PRACTICAL ENERGY AUDIT MANUAL

Foundry & Forge Industry

Prepared by

Tata Energy Research Institute
Bangalore Centre

for

Indo-German Energy Efficiency Project

Tata Energy Research Institute
P. B. 154, Palace Road, Bangalore 560 052
Ph. 2255722 Fax. 2255760
E-mail· teri_blr@vsnl.com

Head Office:
Darbari Seth Block, Habitat Place, Lodi Road
New Delhi 110 003

Contents

Section - 1 : Introduction 1
1.1 Installed Capacity and Production 3
1.2 Exports 3
1.3 Demand Projections 4
1.4 Raw Materials 4

Section - 2 : Technology Outline 5
2.1 Pattern Making 5
2.2 Moulding and Core Making 5
2.3 Melting 5
2.4 Fettling 5
2.5 Inspection and Quality Control 6
2.6 Technology Developments in Castings 6
2.7 Forging Process 7

Section - 3 : Energy Consumption Pattern 9
3.1 Melting 9
3.2 Induction Furnace 10
3.3 Electric Arc Furnace (EAF) 12
3.4 Sand Moulding and Core Making Ovens 14
3.5 Reasons for high energy consumption in Indian Foundry Industry 14
3.6 Factors Affecting Specific Energy Consumption in Forging 15
3.7 Reasons for High Energy Consumption by Indian Forging Plants 15

Section - 4 : Energy Conservation Opportunities 17
4.1 Energy Conservation in Foundries 17
4.1.1 Higher Yields in Iron Foundries 17
4.1.2 Fuel Conservation in Cupola Operation 19
4.1.3 Design Aspects of Cupola 20
4.1.4 Improved House Keeping 26
4.1.5 Regulating Coke 26
4.1.6 Regulating Air 26
4.1.7 Cupola Charge 27
4.1.8 Standardisation of Cupola Operation 27
4.1.9 Reducing Rejections to Improve Yield 28
4.1.10 Utilisation of waste flue gases in Cupola 28

Contents (Contd.)

Section - 4 : Energy Conservation Opportunities (Contd.)

4.1.11 PLC System for Cupola Operation 28
4.1.12 Induction Furnace – Capacity and Utilisation Factor 29
4.1.13 Induction Furnace – Refractory Lining 30
4.1.14 Electrical Losses and Power Factor Improvement 30
4.1.15 Induction Furnace – Charge Raw Materials 30
4.1.16 Induction Furnace Lid and Charging 20
4.1.17 Control of Metal Temperature in Induction Furnace 30
4.1.18 De-slagging of Induction Furnace 31
4.1.19 Molten Heel Practice in Induction Furnaces 31
4.1.20 Induction Furnace Tapping 32
4.1.21 Medium Frequency Core-less Induction Furnaces 32
4.1.22 Energy Balance of Electric Arc Furnaces (EAFs) 32
4.1.23 Charging of EAF 33
4.1.24 Melt Down Practice in EAFs 34
4.1.25 Regulation of Tapping Temperature in EAF 34
4.1.26 Electric Arc Furnace Lid and Charging 34
4.1.27 Refractory Lining of EAFs 34
4.1.28 EAF Capacity Utilisation Factor 35
4.1.29 Efficient Use of Fuel Oil in EAFs 35
4.1.30 Economies of Scale / Size of EAF 35
4.1.31 Use of Water Cooled Panels and Roof in EAF's 36
4.1.32 Oxygen Lancing in EAF 36
4.1.33 Foamy Slag Practice 36
4.1.34 Use of Water-Cooled Chimney in EAFs 36
4.1.35 High Power Transformers for EAF Operation 37
4.1.36 Scrap Preheating 37
4.1.37 Eccentric Bottom Tapping in EAFs 37
4.1.38 Oxy Fuel Burners for EAFs 38
4.1.39 Plant Layout for EAF Operation 38
4.1.40 Submerged Tapping and Liquid Heel in EAFs 38
4.1.41 Ladle Preheating for EAFs 39
4.1.42 Loading of Heat Treatment Furnaces 39
4.1.43 Excess Air Control of Heat Treatment Furnaces 39
4.1.44 Waste Heat Recovery 40
4.1.45 Heat Loss from Openings in Heat Treatment Furance 40
4.1.46 Control of Draught in Heat Treatment Furnaces 40

Contents (Contd.)

Section - 4 : Energy Conservation Opportunities (Contd.)

4.1.47 Minimising Wall Losses in Heat Treatment Furnaces 41
4.1.48 Improved Productivity in Sand Conditioning, Moulding and Core Making 41
4.1.49 Shakeout and Reclamation Systems in Casting 42
4.1.50 Cleaning of Castings 42
4.2 Energy Conservation Opportunities in Forging Industry 42
4.2.1 Heating Furnaces in Forging Industry 42
4.2.2 Optimisation of Fuel Utilisation in Forging 44
4.2.3 Waste Heat Recovery in Forging Industry 44
4.2.4 Effective Maintenance Practice in Forging Industry 45
4.3 Energy Conservation Opportunities in Utilities 46
4.3.1 Compressors 46
4.3.2 Blowers 48
4.3.3 Motors & Drives 50
4.3.4 Electrical Supply System 51
4.3.5 Lighting System 53

Section - 5 : Case Studies 55

5.1 Waste Heat Recovery from Hot Air Venting from FD Cooler 55
5.2 Charge Composition Affects Energy Savings 56
5.3 Optimisation of Furnace Operation 57
5.4 Reducing Delays 57
5.5 Industry Case Study 1 58
5.6 Industry Case Study 2 60
5.7 Switching off FD cooler Fans between Heats 65
5.8 Increasing the Effectiveness of Recuperator of Billet Re-heating Furnace 66
5.9 Industry Case Study 3 66
5.10 Industry Case Study 4 68
5.11 Replacing Refractory Bricks with Ceramic Fibre Blanket 69
5.12 Efficient Ladle Preheating System 71

Section - 6 : Checklist 73

6.1 Coal Fired Furnaces 73
6.2 Oil Fired Furnaces 75
6.3 Electrical Resistance Furnaces 76
6.4 Induction Furnaces 77
6.5 Electric Arc Furnaces 78

Contents (Contd.)

Section - 7 : Economic Analysis of Investments for Energy Conservation 81

7.1 Present Value Criterion 82
7.2 Average Rate of Return Criterion 82
7.3 Return on Investment (ROI) 83
7.4 Pay-back Period Criterion 83
7.5 Break-Even Parameters of Net Present Value 84

Section - 8 : Energy Audit Approach and Methodology 85

8.1 Preliminary Energy Audit (PEA) 85
8.2 Detailed Energy Audit (DEA) 85
8.3 Steps in Energy Audit Programme 86
8.4 Energy Management Practice 92
8.5 The Approach to Energy Management 93
8.6 Preliminary Analysis 93
8.7 Energy Committee 93
8.8 Energy Manager 94
8.9 Energy Management Process/Strategy 94
8.10 Importance of Human Element 96
8.11 Key Tasks of Energy Management 98
8.12 Instrumentation for an Energy Audit 100

List of Annexures

Annexure 1 : Technology Aspects

Annexure 2 : The Forging Process

Annexure 3 : Oxy Fuel Burners

Annexure 4 : Efficient Ladle Pre-heating

Annexure 5 : Combustion equipment

Annexure 6 : Technological Innovations in the Forging Industry

List of Tables

1.1 Distribution of DGTD Licensed and Non-Licensed units 2

1.2 Export of castings 3

1.3 Export of Forge items 3

3.1 Electrical Energy Consumption for Typical Foundry 9

3.2 Typical Energy Balance for a 3-Tonne, 800 kW Mains Frequency Induction Furnace 12

4.1 Summarised Cupola data 21

4.2 Shaft height requirements 22

4.3 Approximate holding capacity of Cupola Well 22

4.4 Typical EAF energy balance 33

4.5 Hearth size for various Forging Equipment 43

4.6 Characteristics of Recuperators 45

4.7 Recuperator Surface area for various heating furnaces 45

4.8 Savings from higher efficiency motors 50

List of Figures

4.1 Effect of well depth on carbon pick up and metal temperature 24

4.2 Effect of well depth on metal temperature 25

4.3 Power Absorbed vs. Metal in Crucible for Core-less Furnace 31

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PREFACE

Energy inputs - both electrical and fuel - are an essential part of manufacturing process, and expenditure on these inputs often accounts for a significant share of the manufacturing cost. This is compounded by the fact that the cost of energy is constantly escalating and will continue to rise.

Any saving in energy costs directly adds to the operating profits of the company. It probably requires less effort to improve profits through energy savings than by - reducing labour cost, increasing sales, increasing prices, reducing distribution costs, etc.

The main purpose of an energy audit is to systematically identify practical and feasible opportunities for saving all forms of energy in a plant and realise the benefit of cost reduction. Experience shows that as much as 10-15 percent of energy could be saved without any need of large investments, through energy audits.

The main objective of this manual is to familiarise the plant personnel in the techniques, methodology and approach to in-house energy audits. Since energy conservation is essentially a continuous exercise, it is inevitable that the plant personnel are able to regularly monitor trends in energy consumption and initiate remedial measures to improve energy efficiency.

Section 1 : Introduction

Energy management is a streamlined and structured concept, devised by management strategists for the efficient use of energy without compromising upon production levels, product quality, safety and environmental standards.

The entire concept, therefore, requires both technical and financial evaluations, along with other considerations such as the human resources, the environmental implications and of course, the ever-present attitude of "no-change" which very often needs a nudge to "change".

Specific energy consumption-the amount of energy consumed per unit of output – varies widely depending on the product in question, type of manufacturing process, type of fuel consumed, age of equipment, size of the plant, operating practices and even to a certain extent the management philosophy. The principle underlying all energy management must be cost effectiveness; conservation should and, is restricted to the extent that it can be justified in normal commercial terms.

The concept of energy management requires a logical and comprehensive management approach. Experience shows that energy savings are only significant and long lasting when they are achieved as part of a plant energy management programme. A systematic and structured approach is required to identify and realise the full potential of savings that can be achieved, mainly through low-cost measures. The energy management programme can be made "self-financing" – with the savings of the low-cost short term measures being utilised for the implementation of more capital –intensive retrofits. The core of such a programme has to be a comprehensive and professional energy audit, in order to assess the current consumption pattern and identify potential opportunities, given the existing framework and infrastructure of the industry.

However, the savings for a plant, just embarking upon an energy management programme, are 20-30% of current consumption patterns.

Energy conservation thus makes very good business sense!

The foundry and forge sector is highly energy-intensive and therefore has been taken up for specific study in this document, as it is highly representative of the core sectors. Typically, the energy cost in this sector is around 20 to 25% of the manufacturing cost.

The industry is a key feeder to the automobile, shipping, machine tools, textile and heavy machinery sectors. Metal castings have been prevalent in India since prehistoric times. Today, there are about 6000 foundries in the organised sector and an equal number in the unorganised sectors with a total capacity of 3.5 million tonnes per annum.

The ferrous casting industry includes iron castings, comprising grey, spheroidal graphite (SG) and malleable iron castings, and steel castings. The steel forging industry caters mainly to the automobiles, oil, engineering, equipment manufacturers, railways and defence. The components used by these industries must frequently meet rigid requirements of strength and toughness, suitable for high speed operation and also amenable to mass production. There is a predominance of small foundries in India.

Forging develops the inherent flow fibres in the metal by proper directional working to provide maximum strength and toughness at points of greatest stress in the finished product. This permits a high strength-to-weight ratio, including a safety margin. The time required for manufacture is low, with lower machining wastage, contributing to lower product cost.

The organised steel forging industry in India is over 50 years old. Steel forging units can be close-die, where the product weighs up to a few hundred kilograms, or open-die, where product weights of 300 tonnes are feasible, although the average ranges around 50 tonne in India. The former, more prevalent with about 300 units all over India, supply components for the automotive sector while the latter supply components for equipment and machinery for steel plants, mining and power generation and are limited to few plants. Table 1.1 shows the region-wise distribution of close-die forging units.

Table 1.1 : Distribution of DGTD Licensed and Non-Licensed Units

Region	DGTD Units	Non-DGTD	Total
North	13	145	158
East	12	24	36
West	28	51	79
South	7	28	35
Total	**60**	**248**	**308**

1.1 Installed Capacity and Production

The capacity and production statistics indicate that there has been gross under-utilisation in the organised sector, primarily due to large scale imports of castings under project imports, non availability of iron and steel scrap, pig iron and coal, power cuts and technological obsolescence, combined with the general industrial recession. For the past few years, the capacity utilisation has hovered around 50 to 60%.

1.2 Exports

Exports of iron and steel castings have not been very significant, with a value of around Rs. 600 crores during 1998-99. A major part of these exports are sanitary castings. Table 1.2 shows the export of castings for the past three years, mainly to Australia, Belgium, Denmark, Indonesia, Japan, Kuwait, Malaysia, Oman, Sri-Lanka, Thailand, U.K., USA, Bangladesh, Canada, China, France, Germany, Italy, Netherlands, New-Zealand, Singapore, UAE and Zambia. Table 1.3 shows the export of forge items for the past five years, mainly to Australia, Belgium, Cannada, France, Germany, Indonesia, Saudi Arabia, Sri Lanka, UAE, UK, Denmark, Italy, Japan, Malaysia, Singapore, Spain and USA.

Table 1.2 : Export of Castings (Rs. In Crores)

Year	Value	% of Exports
1996-97	467	3.12
1997-98	503	2.94
1998-99	575	3.31

The low exports are largely due to shortcomings to international standards, competitive prices and timely delivery.

Table 1.3 : Export of Forge Items (Rs. In Crores)

Year	Value
1993-94	104.62
1994-95	108.35
1995-96	162.83
1996-97	216.73
1997-98	183.15
1998-99	241.76*

*Estimated

The major barriers to improving exports are prohibitive prices, mainly due to high input and energy costs, and technical deficiencies in some cases. A comparison between domestic and international cost / price of forging indicates that Indian costs are higher by 134%. This gap needs to be bridged by the Indian industry through measures to improve efficiencies of both energy and material use, combined judiciously with technological up-gradation.

1.3 Demand Projections

The demand for iron and steel castings has been projected to grow at 4% on an average. The projections indicate a higher growth of 9% for iron castings. The estimated growth from the automobile sector alone is about 15%. The growth in this sector, combined with the shutting down of foundries in developed countries, due to environmental legislations, precurses a potential for the growth of exports. This, however, calls for modernisation and rehabilitation of their plants, primarily to reduce cost of production.

The demand will also be affected by the development of products and processes to substitute forging by many industries such as automobiles and diesel engines, such as cold forged parts, SG Iron castings and powder metallurgy, combined with the need, for lighter design and increased precision.

1.4 Raw Materials

The raw materials for manufacture of iron castings are pig iron, steel scrap and coke. In addition, ferro alloys such as ferro-chrome, ferro-manganese, ferro silicon and other alloys such as magnesium and nickel are used for various specifications of iron castings. High ash content of 25 - 40 % against a desirable value of 20%, combined with irregular size of coke, also tend to pose problems for iron foundries.

The main raw materials for steel foundries are steel scrap and coke, along with alloying elements, such as ferro-manganese, ferro-silicon, ferro-chrome, ferro-molybdenum are used, depending upon the chemical composition of the product. Foundry grade sand is available in the country, but there is lack of washing and grading facilities.

Annexure 1 discusses some technology aspects of the foundry industry.

Section 2 : Technology Outline

Casting is essentially a process of pouring molten metal into a mould and allowing it to solidify, to obtain intricate shapes, sections and profiles. Depending upon type, size, weight, intricacy, tolerance and surface finish, various moulding and casting processes such as green or dry sand moulding, gravity casting, shell moulding and die casting are employed.

2.1 Pattern Making

After designing a product, the first step is to create a pattern, machined from wood, plastic or metal depending upon the number of castings required. The material and quality of manufacture of the pattern significantly influence the quality of a casting.

2.2 Moulding and Core Making

Most foundries use the green sand moulding process, using silica sand is used more universally for making castings than any other moulding material. A suitable bonding agent like clay is mixed to make an aggregate suitable for moulding. To avoid the problem of blowholes in green sand moulding at low permeability, dry sand moulds are used. Dry sand moulds produce more accurate castings and are less susceptible to breakage, cracking and blowholes.

2.3 Melting

A cupola is used in foundries for melting, because of high electrical energy cost and erratic power supply. However, due to shortage of pig iron supply and increased use of scrap, metal melting furnaces play an important role in foundries. The choice of the furnace is generally dictated by initial cost, base cost of operation, availability and relative cost of various fuels and speed of melting.

2.4 Fettling

After the castings are removed from the mould, gates and risers, which occur in any refractory used for moulds or cores, which continue to adhere to the mould must be fettled. This is an expensive operation. Most Indian foundries adopt manual fettling methods, although manipulators and machines for cleaning are finding use.

2.5 Inspection and Quality Control

The castings are visually inspected and gross defects repaired, before further inspection. Radiographic and other optical methods are used increasingly. The use of statistical quality control is a promising development for foundries, wherein only a sample is inspected. Other methods of inspection include magnetic tests, fluorescent powder, ultrasonic, reflectoscope, vibration tests and metallographic analysis.

2.6 Technology developments in Castings

The advent of fuel efficient engines with better performance and increasing sophistication of machine tools and other engineering products has increased the need for close tolerance, high strength, thin walled, quality castings.

However, the Indian foundries still maintain a low level of technological sophistication in moulding and core making processes, although melting and foundry mechanisation is more advanced. The labour productivity is far below that achieved internationally.

Some areas of technological obsolescence include computerised drafting, computer graphics for design and evaluation of patterns and CNC/NC pattern making equipment.

New developments are available such as:

- High speed sand mullers with integrated unit sand system for moulding and sand preparation
- High pressure hydraulic moulding machines with full automation
- Automatic charging and pouring for electric arc furnaces and induction furnaces
- Vacuum emissions spectrometers
- Computerised charge optimisation
- Fettling and inspection facilities including resonant vibrators for de-coring, hydroblast and chemical cleaning, automatic grinding and de-burring
- On line ultra-sonic and x-ray scanning.

Very few foundries in the country have installed such equipment. Only castings of medium weights (for power plants, cement plants, mining industry) are being produced in the country, while castings above 60 tonne weight are yet to be developed indigenously.

2.7 Forging Process

The hot forging in India is similar to the process used in advanced countries, although the latter adopt more mass production techniques, advanced forging processes, furnaces, tooling and material handling systems, all of which enable economic and quality of production. In the absence of an established production base for such equipment, most modern forging equipment need to be imported by the domestic industry, except small capacity hammers, presses and hacksaw machines. The forging process is discussed in detail in Annexure 2.

Section 3 : Energy Consumption Pattern

The major energy consuming areas in typical foundry units can be classified into four areas:

- Melting and re-heating
- Heat treatment
- Utilities such as compressors, blowers and pumps
- Foundry equipment

Table 3.1 shows the typical electrical energy consumption in a foundry, while thermal energy is typically consumed at the furnaces or cupola.

Table 3.1 : Electrical Energy Consumption for a Typical Foundry

Unit	% Electrical Energy Consumption
Melting and Holding Furnace	86.0
Sand Plant	3.6
Baking Oven	0.8
Compressors	4.4
Lighting	1.4
Miscellaneous	3.8
Total	100.0

At the outset, some of the operations are discussed for their relevance to energy consumption.

3.1 Melting

Melting consumes a substantial portion of the thermal energy, and some part of the electrical energy in the total energy consumption. Cast iron, for iron castings, is commonly melted, either in a cupola or in an electric induction furnace. For steel castings, the melting takes place either in an Electric Arc Furnace (EAF) or in an electric core-less induction furnace.

Cupola Melting

The cupola is a vertical shaft furnace. It consists of a mild steel shell lined with refractory. Iron, coke and fluxing agents are fed in at the top on to a bed of coke. Combustion of coke takes place in the lower portion of the cupola, and the molten iron and slag run to the bottom of the shaft. The cupola is periodically tapped to draw off this molten iron and slag. The hot waste gases pass upward through the charge and in doing so, preheat it. The gases finally exit at the top of the shaft.

The combustion air may be either at ambient temperature (cold blast cupola) or pre heated (hot blast copula). Combustion air preheating is achieved either by external direct firing or by recuperation of the hot waste gases, the latter being obviously more energy efficient.

Cold-blast Cupolas operate continuously over a fairly short melting campaign of less than 12 hours. It is a common practice to operate them in pairs so that, at any one time, one is melting and the other undergoing maintenance and repairs.

Hot blast cupolas generally melt for much longer periods and often only a single cupola is installed.

The coke consumption of a cupola is generally 100-170 kg per tonne iron melted or 2.4 - 4.1 GJ/tonne, and implies a maximum thermal efficiency of 50%, given that the theoretical energy required to melt cast iron and raise its temperature to 1450^0C is 1.4 GJ/tonne. However, size, operating practice, campaign life and tapping temperature all affect the coke consumption. Large hot blast cupolas tend to give the lowest specific energy consumption.

The major drawback of cupola melting is the high level of dust contamination in the waste gas stream, from sand in foundry returns and coke ash. A waste gas cleaning / filtration plant becomes mandatory so that the cupola can comply with environmental legislation. This can add considerably to the capital and operating costs.

3.2 Induction Furnace

The core-less induction furnace can achieve a high melting rate with accurate temperature control and minimal contamination of charge. Core-less furnaces were traditionally designed to operate at mains frequency of 50 Hz with a molten heel Medium frequency furnaces operating between 150 and 1000 Hz pose a serious challenge to the mains frequency furnaces because of their ability to operate without molten heels and smaller size.

The working of the induction furnace is based on the principle of electromagnetic induction and the basic concept is same as that of a transformer, but with a single turn, short-circuited secondary winding. The charge to be heated and melted forms the secondary, while the hollow water-cooled copper coils excited by AC supply form the primary.

In core type furnaces, the channel is loop connected at both ends with the main bath. As the metal in the channel is heated, convection currents push hot metal upward into the bath and draw cold metal down into the channel. This distributes the heat in the main bath and generates a stirring of the melt in a reasonably short time. This, combined with the effective atmosphere seal achieved, maintains melting losses at low level. The supply frequency is invariably 50 Hz. The electrical efficiency is higher than that of other types of induction furnaces; the natural power factor is 0.5 to 0.7 and does not fall off appreciably during long campaigns. Thus, the number of power factor correction capacitors is much less than that required for core-less furnaces.

The core-less induction furnace consists of a crucible formed by a rammed refractory lining completely surrounded by a multi turn, cylindrical, water-cooled copper coil. An invaluable feature, inherent in induction furnaces and particularly noticeable in the core-less type, is a powerful stirring action produced in the melt by the interaction of the fields due to the currents flowing in the coil and the charge respectively. The intensity of movement is influenced by the frequency of the coil supply, the furnace capacity and the applied power. In a particular installation, the furnace capacity will be determined by casting requirements; the power input by the required melting rate.

Core-less induction furnaces are operated at various frequencies; usually 50 Hz mains frequency, 150 Hz triple frequency and 250 to 5000 Hz medium frequencies. However, there are small units that operate on high frequencies of up to 10 kHz. The frequency at which the furnace operates affects the ease with which melting can start from cold. Furnaces operating at mains frequency are normally worked with a heel of molten metal, not essential for higher frequency furnaces. To start the core-less furnace, scrap of the chosen size is packed in the crucible or a starting plug is used, while no starting plug is necessary with high frequency furnaces.

Table 3.2: Typical Energy Balance for a 3-Tonne, 800kW Mains Frequency Induction Furnace

Parameter	%
Heat Input	66.25
Heat Output	
Coil Losses	20.00
Radiation Loss through roof openings	2.75
Conduction Loss	4.75
Ancillary system losses (distribution circuit, capacitor, inductors etc)	6.25

3.3 Electric Arc Furnace (EAF)

The EAF process involves melting of scrap by the application of intense heat generated by an arc struck between graphite electrodes. Once the scrap melts, the metal is analysed for carbon and other elements. Other alloying elements are added while refining, depending upon the grade of steel required to be produced.

The arc furnace has an outer cylindrical shell, lined with refractory bricks to protect it from high temperature and corrosive nature of the melt, and a detachable roof also lined with refractory bricks. Three carbon electrodes with water-cooled jackets are introduced through openings in the roof. The energy for melting is generated by a 3-phase low voltage, high ampere current passed through the electrode.

The three electrodes are made of graphite rods supported on an electrode arc. The electrode arcs should be rigid enough to bear mechanical resonance frequencies and other dynamic forces acting on the arm. The consumption rate of electrodes depends upon various factors such as quality of the electrode material and melting practices.

The charge, comprising light and heavy scrap, and in some cases, sponge iron is dropped into the furnace in stages. The electrodes are lowered to strike an arc between the electrode tip and scrap material to convert electrical energy into thermal energy for melting. Oxygen can be injected through a lance during melting, to react with the steel, enhancing melting rate, reducing melting time, increasing furnace productivity and thus reducing specific consumption of electrical energy.

Refining of molten metal is done by adding fluxes and de-carborisers. The slag is removed from the front door of the furnace. The chemical composition of the metal is adjusted by the addition of ferro-alloys and oxygen lancing, while the temperature of the melt is raised to attain the tapping temperature. Oxygen injection also speeds up the refining process. After refining, the molten steel is tapped through the furnace spout and cast.

Although the efficiency of the EAF is high during melting, this level is not maintained during refining. Also, only 40% of the available transformer power rating is used during this stage. Therefore, a better practice is to use the EAF primarily for melting and use the ladle for refining. A ladle refining station can be connected to a separate heating source, with provisions for addition of ferro-alloys, fluxes and injection of oxygen.

A furnace transformer, usually rated at 350-450 kVA per tonne furnace capacity, supplies the electric energy used for melting. The three electrodes are connected across the secondary of the transformer, with on-load variable-voltage tap-changers. Desirable parameters of the electrical system include **low electrode current,** arc stability, over current and furnace insulation from supply during charging and tapping.

EAFs are designed to work throughout the year on a three-shift basis. The furnace availability depends upon scheduled down time on account of preventive maintenance, refractory repairs between heats and relining, mechanical and electrical breakdown, power cuts and interruptions.

Yield, defined as the output from one tonne of raw material charged, can vary depending on the grade of scrap and its relative contamination. Clean segregated scrap obviously has a better yield factor. The yield also varies with the type of casting, such as ingot or billet.

The theoretical electrical energy requirement for melting one tonne of steel from room temperature to 1500oC will be about 342 kWh (to be confirmed from mini steel plant manual), but the actual power consumption during the melting state has been much higher than this figure (varying from 400 to 525 kWh per Mt of liquid metal). The electrical energy in the refining stage is reported to be in the range of 200 to 300 kWh/ Mt liquid metal (mild steel).

Apart from the requirement for melting and refining there is the requirement for auxiliaries such as for water cooling in arc furnaces and concast machines, scrap handling and charging. On an average the total electrical energy required per tonne of finished ingots/billets inclusive of auxiliary load is reported to be in the range of 600 to 700 kWh/Mt.

3.4 Sand Moulding and Core Making Ovens

The sand moulds and cores are baked at higher temperatures. The system consists of either a vertical rotary type or batch type oven fired by oil or coal.

Heat Treatment Furnaces

Finished and semi-finished castings are often heat treated to modify their metallurgical properties, using mostly intermittent furnaces. The operations normally performed are tempering, hardening batches of castings at temperatures between 400 and 1000^{0}C.

Air Compressors

Compressed air is mainly used for operating the moulding machines, pneumatic grinders, mould cleaning and miscellaneous uses. Most foundries and forging industry use compressed air at 7 kg/cm^2.

Material Handling Equipment

This is vital operation, wherein the equipment consists of sand conveyors, cranes and hoists. The conveyors transport the sand from the storage yard to the sand drier and then to the moulding section. The knock-out sand from the mould boxes is returned through another conveyor. Cranes are used for charging scrap, moving ladles, positioning mould boxes and transporting castings.

3.5 Reasons for high Energy Consumption in the Indian Foundry industry

- Quantum of rejects
- Size of castings, since larger castings reduce energy consumption
- Energy efficient controls
- Computerised automation and energy monitoring system.

3.6 Factors Affecting Specific Energy Consumption in Forging

In open-die forging, the processes are generally serviced by a number of oil or gas-fired furnaces for heating ingots or re-heating forged pieces. The intermittent operation involved results in high structural heat losses.

In close-die forging, about 85% units adopt oil firing, while the rest use electricity. Gas firing has not yet become an established concept in the industry. The furnaces are generally batch-type, although some units also use rotary and slit type furnaces. Continuous furnaces, which are more efficient, are used only by a few large units.

Heat treatment of a forging is generally an in-house operation, in oil-fired batch furnaces, although a few electric pit furnaces are prevalent.

3.7 Reasons for High Energy Consumption by Forging Plants

Some factors tending to increase energy consumption in the Indian industry include:

- Poor combustion efficiency - Improper temperature and pressure for furnace oil atomisation, due to lack of pre-heating and pumping units, instruments such as oil pressure gauges, temperature indicators, pressure regulators and oil filters
- Lack of waste heat recovery facilities, despite their obvious potential for fuel economy of 20 to 25%
- Oversized furnace and intermittent loading or under loading affecting thermal efficiency of the furnace
- Improper draft control - in the absence of proper flues for products of combustion, furnaces operate under heavy pressure, with higher fuel consumption.
- Obsolete furnace designs, with no specialised design
- Under utilisation of equipment to only 50 to 60% mainly due to small batch quantities, resulting in frequent die changes and higher idle time, poor quality of die steel and reduced die life, lack of orders and low grade product-mix.
- Lower material yield due to poor raw material quality, over-design practices, wastage in cutting and high scale losses.
- Labour productivity in Indian plants is low at around 18 tonne per man-year, compared to 100 to 120 tonne per man-year in developed countries, mainly due to lack of consistent load and lower automation level.
- Obsolete die designs have led to wastage of material in forging, with higher consumption of material and resources.

Although the main reason behind all these factors has been the lack of capital to invest in energy conservation measures, this document explores specifically those areas where investments are low and payback period is less than three years, in order that such measures are realistic and feasible.

These measures are discussed more elaborately in the next section.

Section 4 : Energy Conservation Opportunities

Although development of new techniques and equipment for melting, charge handling, processing, pouring, analysing and laboratory testing have contributed towards improvement in casting quality and energy conservation, there is still tremendous potential to increase the extent of conservation. The energy conservation measures also generally result in higher productivity, cleaner environment and safer operating conditions for the workforce.

In foundries, fuel and power generally constitute 20 to 25% of the cost of energy of the value added and 10 to 12% to the cost of production during metal casting operations. Where cupolas are used, hard coke constitutes a significant part of the cost of fuel. Foundries producing steel castings mainly consume electricity. Wood and furnace oil are used for core baking ovens and electricity for providing motive power to blast blower, hoists, machine moulding, shot blasting, grinding and ancillary equipment, and also lighting loads.

4.1 Energy Conservation Opportunities in Foundries

4.1.1 Higher Yields in Iron Foundries

High yields depend largely on good foundry practices: the key areas are the melting and pouring sections, the moulding and core-making departments, with emphasis on methoding.

The melting and pouring section must deliver metal into the moulds at appropriate temperatures and required compositions. While it is important that unsatisfactory metal is pigged rather than poured into moulds, the amount of pigged metal should be monitored and action taken to peg it down.

Automatic pouring units can provide significant improvement in foundry yields due to their higher accuracy and consistency. Various computer programs now offer considerable assistance for running and feeding iron castings.

Good practice in moulding and core-making, especially quality control of inputs, can dramatically affect levels of foundry scrap. Reducing scrap has a two-fold effect:

- Less energy is required for metal melting;
- The cost of energy, materials and labour, particularly in moulding and core-making, is reduced, thus increasing the potential capacity.

Accurate measurement of metal and a metal balance can help identify action priorities and pin-point sources of metal loss in pigging or runners. Foundry yields must be broken down for various metal types such as grey or ductile iron, and for different moulding techniques. Fig 4.1 shows the various stages where metal is lost during a foundry operation.

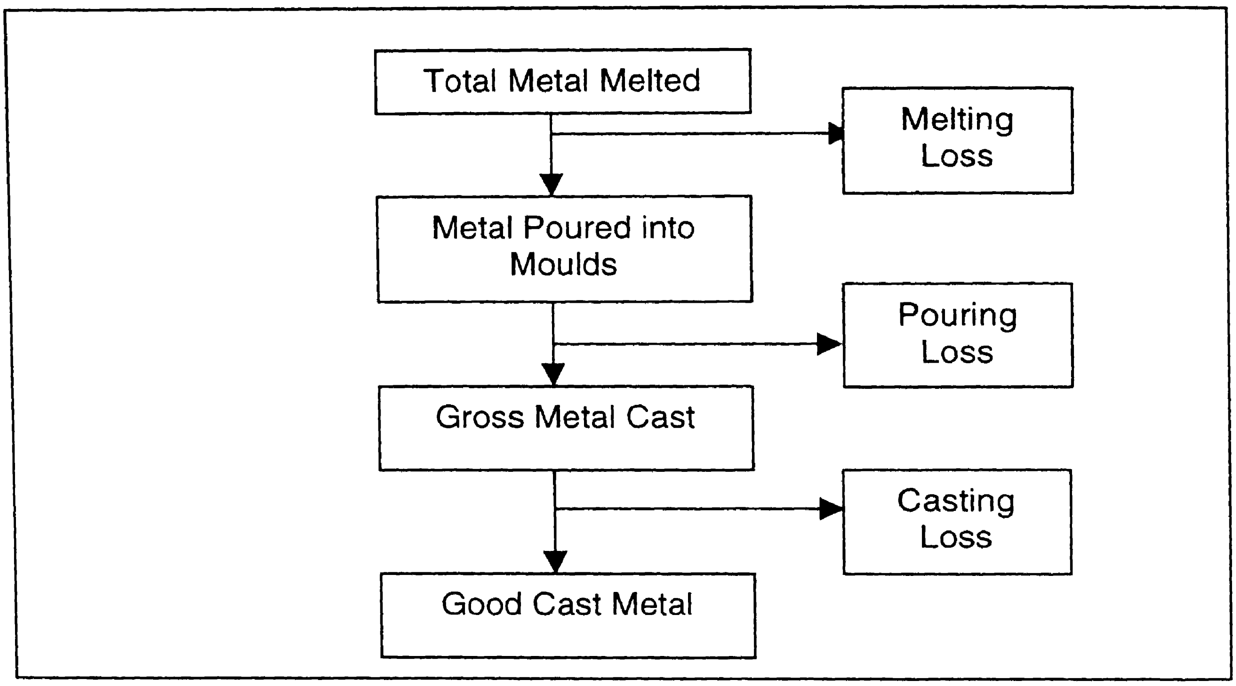


Fig. 4.1 : Metal Loss at Various Stages

Metal loss is mainly due to melting furnace operations such as oxidation, slagging and test pieces, as small pieces of split metal, and as metal chipped or ground off castings during fettling. These amount to 5% to 10% of the metal melted. The rest of the excess metal, i.e., the pigged metal, runner systems and scrap castings, is returned for re-melting. A typical grey iron foundry could operate at a yield of approximately 65%. Careful scheduling, efficient runner design and effective scrap control can all improve yield significantly. The yield also depends upon the type of casting and grade of metal. Malleable iron castings could achieve a 35% to 45% yield, while very specified grey iron castings may provide a yield of 90%.

Obviously, increasing yield will reduce the energy consumed, since the melting furnace is the chiefly energy-intensive section of the foundry. Improving foundry yield can provide a cascading benefit. Considering a relevant example:

Normal production	:	50 tonnes good castings from 100 tonnes melt
Normal Yield	:	50%
Improvement in Yield	:	10%
New Yield	:	60%
Melt for 50 tonne castings	:	83.3 tonnes
Reduction in metal required	:	16.7 tonnes

If a cupola furnace with a 14% coke charge is used for melting, about 2.4 tonnes of coke can be saved for every 50 tonnes of good castings produced. This could translate to a saving of about 14000 kWh in an electric melting furnace.

It is important to establish a metal balance so that quantities of metal involved in the various aspects of loss or recycling can be clearly demonstrated. The metal balance should cover:

- Melting loss (with estimated breakdown)
- Pigged metal
- Split metal
- Runners and risers
- Grinding losses
- Scrap castings
- Good castings

4.1.2 Fuel Conservation in Cupola Operation

Iron foundries operating on cupola use hard coke, which is a major input cost, second only to pig iron and scrap. On an average, in Indian foundries, the pig iron-coke ratio is around 4:1, with some units going up to a ratio of 5:1. There are two ways to reduce coke consumption in the foundry:

- Simple housekeeping measures during melting, incorporating marginal design modifications for improving melting rate which reduce specific energy consumption.

- Reduction of rejection rate to improve cast yield to metal charge. This would require innovative techniques to improve moulding practices, redesign of casting and improvement in layout to improve quality, productivity and utilisation of hard coke.

4.1.3 Design Aspects of Cupola

In practice, the optimum blast rate varies to some extent with the metal to coke ratio and the nature of the materials melted. However, it has been found both experimentally and practically, that the optimum blast rate is approximately 115 m^3/min per m^2 (375 ft^3/min per ft^2) of cupola cross-sectional area at the tuyeres. This figure may be taken as the first fundamental basis of design. Table 4.1 shows summarised cupola data and gives the optimum blast rate (in column 2) for cupolas of varying cross-sectional area (in column 3) and diameter (in column 4).

Internal Melting Zone Diameter

Blast rate controls the specific melting rate of a cupola and the attainable temperature at any specified coke rate. The optimum specific blast rate cannot be achieved if too large or small a furnace is specified.

A guide to the internal diameter and area of melting zone required for a range of metal : coke ratios is given in Table 4.1. With knowledge of the blowing rate, the melting zone area (column 3) can be calculated, based on a specific blast rate of 115 m^3/min per m^2 of melting zone area, and from this the internal diameter of the furnace can be calculated (column 4).

External Shell Diameter

When the internal diameter is known, the external shell diameter can be derived from the specified lining thickness. Generally, a thickness of 22.5 cm (9 in) is satisfactory for a melting period of up to four hours. For a longer period (up to about eight hours) the lining thickness should be at least 30 cm (12 in).

Shaft Height

The required shaft height for cupolas at various melting rates is given in Table 4.2. These shaft heights optimise the pre-heat for the descending burden. However, if the gas is required to burn at the charge hole, a shorter shaft height may be considered : the shorter the shaft, the hotter the top gas and the greater the ease of combustion – either spontaneous or assisted by an after-burner.

Table 4.1: Summarised Cupola data

1			2		3		4		5				6		7		8	9	
Approximate melting rate at various metal:coke ratios under steady operating conditions t/h.ton/h			Recommended blowing rate *		Cross-sectional area of melting zone		Diameter of melting zone		Recommended blower capacity †				Approximate well capacity		Total tuyère area		Number of tuyères	Approximate bed weight	
Metal:Coke ratio									Volume		Discharge pressure								
10:1	8:1	6:1	m^3/min	ft^3/min	m^2	ft^2	cm	in	m^3/min	ft^3/min	kPa	in w g	t per m height	cwt per ft height	cm^2	m^2		t per m height	cwt per ft height
1.6	1.3	1.1	18.5	665	0.16	1.77	45	18	22	800	10.0	40	0.6	3.6	300	45	4	0.07	0.4
2.2	1.9	1.5	25.5	900	0.22	2.40	52.5	21	30	1080	10.5	41	0.8	4.8	400	60	4	0.10	0.6
2.9	2.5	1.9	32.0	1180	0.28	3.14	60	24	40	1420	10.5	42	1.1	6.3	450	70	4	0.13	0.8
3.7	3.1	2.5	41.5	1495	0.36	3.98	67.5	27	50	1800	11.0	43	1.3	8.0	550	80	4	0.17	1.0
4.5	3.9	3.1	50.5	1840	0.44	4.91	75	30	60	2200	11.0	44	1.6	9.8	600	95	4	0.20	1.2
5.5	4.7	3.7	61.0	2230	0.53	5.94	82.5	33	75	2680	11.5	45	2.0	11.9	700	110	6	0.25	1.5
6.6	5.6	4.4	73.5	2650	0.64	7.07	90	36	90	3180	11.5	46	2.3	14.0	800	120	6	0.30	1.8
7.7	6.5	5.2	86.5	3110	0.745	8.30	97.5	39	105	3740	12.0	47	2.8	16.5	900	130	6	0.35	2.1
9.0	7.6	6.1	100.0	3620	0.87	9.64	105	42	120	4350	12.0	48	3.2	19.0	1000	150	6	0.40	2.4
10.3	8.7	6.9	115.0	4140	1.00	11.04	112.5	45	140	4970	12.5	49	3.7	22.0	1100	160	8	0.47	2.8
11.7	10.0	7.9	130.0	4720	1.13	12.57	120	48	155	5660	13.0	51	4.2	25.0	1150	170	8	0.52	3.1
13.2	11.2	8.9	145.0	5300	1.28	14.19	127.5	51	175	6360	13.0	52	4.7	28.0	1200	190	8	0.58	3.5
14.8	12.6	10.0	165.0	5950	1.43	15.90	135	54	200	7140	13.5	53	5.3	32.0	1300	200	8	0.67	4.0
16.5	14.0	11.2	185.0	6650	1.60	17.72	142.5	57	220	7980	14.0	55	5.8	35.0	1400	220	8	0.73	4.4
18.3	15.6	12.4	205.0	7360	1.77	19.63	150	60	250	8850	14.5	57	6.5	39.0	1500	230	8	0.82	4.9
22.1	18.8	14.9	245.0	8900	2.14	23.75	165	66	300	10700	15.0	60	7.8	47.0	1700	260	10	1.00	6.0
26.5	22.5	17.9	290.0	10650	2.55	28.27	180	72	350	12700	16.0	63	9.3	56.0	1800	290	10	1.20	7.1
31.1	26.4	21.0	345.5	12500	3.00	33.18	195	78	410	1500	17.5	69	11.0	66.0	2100	320	10	1.40	8.3
36.1	30.6	24.3	400.0	14500	3.46	38.47	216	84	480	17400	19.0	75	13.0	77.0	2200	350	10	1.60	9.6

* Actual blowing-rate specified at 155 m^3/min for each m^2 of cupola cross-sectional area in the melting zone (375 ft^3/min for each ft^2) to take into account satisfactory cupola operation at values within ±20% of this figure. Air volumes refer to measurement at 15°C (60F), 1.315 kPa

† Recommended blower-volume capacity based on recommended blowing rate in Column 2 plus 20%, discharge pressure approximately 50% higher than anticipated windbelt pressure

Table 4.2 : Shaft height requirements

Melting rate of cupola (t/h)	Height from tuyeres to charging door still (m)
Up to 5	4.9
5 – 8	5.8
Over 8	6.7

Size and Number of Tuyeres

Column 7 of Table 4.1 gives tuyere areas for a range of approximate air velocities from 10 m/s (35 ft/s) for a 45 cm (18 in) diameter cupola, up to 30 m/s (100 ft/s) for a 210 cm (84 in) diameter cupola.

As the diameter of the furnace increases, more tuyeres are needed to give even blast distribution; the number of tuyeres required is given in column 8 of Table 4.1.

Well Depth

The depth of the well, i.e., the distance from tuyeres to tap hole, affects the chemical composition and temperature of iron produced in intermittently tapped or continuously tapped cupolas.

Intermittently Tapped Cupolas

Table 4.3 gives the capacity of cupola wells of various diameters, assuming that half of the well volume is occupied by coke. When deslagging is carried out every hour, an allowance of about 38 cm (15 in) should be made for the slag when estimating well depth.

Table 4.3 Approximate holding capacity of Cupola well

Diameter of well (cm)	Iron holding capacity (kg/cm depth)
46	6.0
53	8.0
61	10.5
69	13.3
76	16.3
84	19.8
91	23.3

Diameter of well (cm)	Iron holding capacity (kg/cm depth)
99	27.5
107	31.7
114	36.7
122	41.7
130	46.7
137	53.3
145	58.3
152	65.0
168	78.3
183	93.3
198	110.0
213	128.0

It should be remembered that no heat is generated in the well, but that heat is lost through the lining. Therefore, too deep a well increases the temperature loss of the metal held and, in addition, may impede complete uniform ignition of the coke bed beneath the tuyeres, resulting in cold metal during the early part of the melt. To meet the requirements for mixing capacity, the weight of the metal charges should be selected to provide mixing capacity without unduly increasing well depth; this can usually be achieved by restricting the metal charge weight to a tenth or less of maximum hourly output. The well collects the metal and slag melted in the upper part of the cupola and lets the two separate. The required well depth may be calculated as follows :

Internal diameter of cupola well	122 cm
Weight of metal charges	800 kg
Required metal-holding capacity (equivalent to 3 charges)	2400 kg
Metal holding capacity of well (Table 1)	41.7 kg/cm depth
Well depth required for metal	58 cm
Allowance for slag	38 cm
Total well depth required	96 cm

Continuously Tapped Cupolas

In continuously tapped and deslagged cupolas, very little metal is held in the well; mixing capacity is normally provided by a receiver or collecting ladle, but the depth of the well should always be sufficient to prevent slag entering the tuyers at the lowest anticipated blast rate to be used.

The actual depth of the well has an important influence on carbon pick-up and the tapping temperature of the metal as shown in Fig 4.1.

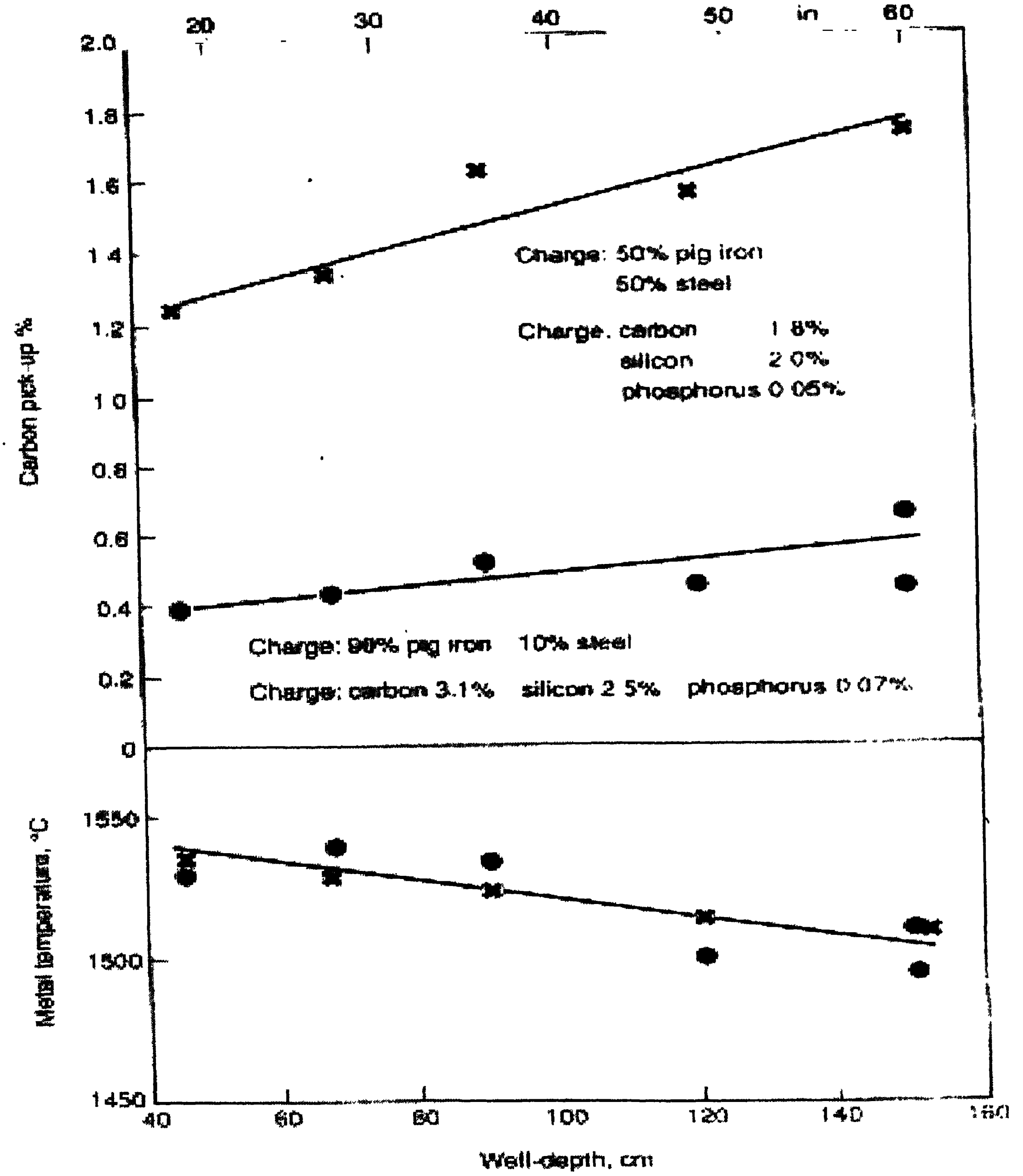


Fig. 4.1: Effect of well depth on carbon pick up and metal temperature: 760 mm cold blast cupola.

Fig.4.1 shows how carbon pick-up increases and the tapping temperature decreases with increasing well depth in a 760 mm (30 in) diameter cold blast cupola. The influence of well depth on carbon pick-up is more marked when the charges melted are of low carbon content (that is, high steel charges), and the effect on metal temperature is more pronounced at the beginning of the melt, as shown in Fig. 4.2.

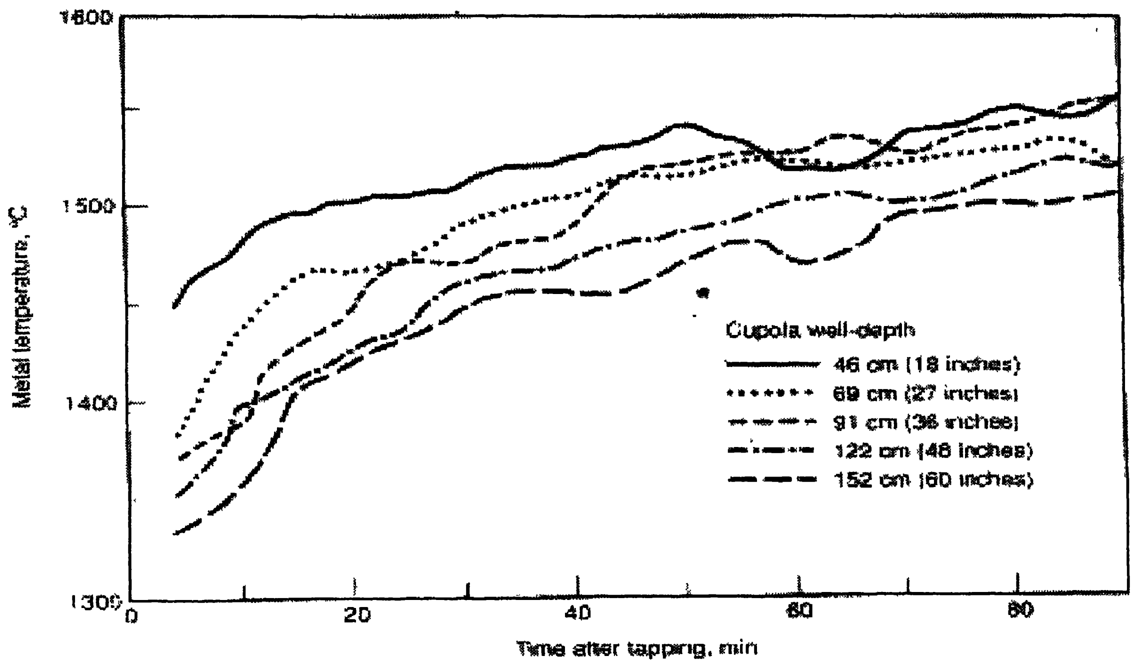


Fig. 4.2: Effect of well depth on metal temperature.

If the depth of the well is increased to obtain additional carbon pick—up, temperature loss must by accepted, although it may be compensated for by using either oxygen injection or enrichment in the combustion air, or by using an electrically heated holding furnace if available.

The effect of well depth on carbon pick-up has been exploited in the design of modern hot blast cupolas, by appropriate adjustment of the distance between tuyeres and tap hole. Carbon pick-up can be regulated so that malleable iron of low carbon content, or grey iron of relatively high carbon content, can be produced from charges consisting of cast iron and steel scrap with little or no pig iron when operating with acid slags. For malleable iron the cupola would have a shallow well, whereas for grey iron the cupola would have a deep well.

The well depth should be deep enough to :

- ensure good mixing of the molten iron;
- let a single tap produce the largest casting;
- hold all the slag produced before deslagging;

4.1.4 Improved House Keeping

Although poor coke quality and untrained manpower continue to be realities, the Indian foundry industry also does not pay enough attention to melting practices. More emphasis is laid on mould design, order procurement and raw materials, rather than actual melting practice. Most cupolas are operated intermittently, once or twice a week, or lesser. In smaller units, inadequate attention is paid at the design stage for the right quantity and draught of air, both of which are crucial for efficient operation of the cupola furnaces. Many a time, cupola furnaces are found smoking, quite unable to melt the requisite quantum of pig iron, due to poor quality of coke, steel scrap and limestone.

An in-depth study of the operation of these furnaces can achieve fuel economy by better operation and maintenance practices, marginal modifications in the design to facilitate better operational efficiency and adherence to standard operating practices.

4.1.5 Regulating Coke

Operational

One of the most common causes of inefficient cupola operation is mismatch between cupola diameter and output. For efficient melting conditions, the cupola must be operated to melt 0.6 tonne/hour per sq.ft of cross section area of melting zone. Lower melting rates will lead to lower metal temperature and higher melting losses.

If the cupola is operated to produce less than 0.6 tonne/hour per sq.ft there is scope to reduce coke consumption by decreasing internal diameter of the cupola and raise the melting rate.

The height of the coke bed is an important consideration. Ideally the coke bed should be measured with a gauge and maintained to about 2 feet. Coke thickness may be increased if high carbon pick up is required.

The most effective coke would be premium quality hard sized coke of normally 6" size. The size of metal charges also affects fuel efficiency. Large pieces could be broken to less than 6" inches.

4.1.6 Regulating Air

Operational

Adequate air should be supplied for efficient combustion of coke, at the right pressure to achieve the required turbulence for Indian coke. Low pressure or inadequate air supply reduces melting rates, with higher coke consumption. This is stated to account for failure to achieve the desired melting involving high coke consumption. A 34-inch cupola would need about 2000 ft^3 of air volume at 20 to 22" water gauge pressure.

A well-designed blower supplies constant volume of air to the cupola at varied pressures. The blower design, of vane angle, number of vanes and impeller diameter are thus important parameters in selecting a blower. Air leakage at tuyere cover plates, wind belt and blast mains must be arrested to improve operating efficiency. When twin cupolas are operated using a single blower, air leakage from the blast gate or valve, which cuts off air supply of one cupola when the other is running, must be arrested.

A key to successful cupola operation is to attain steady state combustion. A proper balance of air and coke ensures efficient combustion, with increased bed temperature and a more fluid slag. Fluid slag has more affinity for sulphur, thus making it easier to obtain low-sulphur metal. Fluid slag also does not adhere to the coke surface. This exposes more surface of each lump of coke, for more efficient combustion or a better coke to iron ratio. The hot metal and fluid slag flow freely and do not adhere to the refractory lining of the cupola walls. A pressure gauge is a valuable instrument, which should be attached to every cupola. However, it is not a substitute for a cupola blast volume meter. With both the meters on the cupola panel board, conditions inside the cupola can be assessed accurately.

4.1.7 Cupola Charge

Operational

For better consistency in metal composition, individual quantities of metal flux and coke must be carefully calculated and consistent with the composition of the castings to be produced. An accurate and suitable weighing arrangement should be incorporated into the charging system without providing an impediment to the flow of raw materials.

4.1.8 Standardisation of Cupola Operation

Operational

Standardisation involves studying melting practices to pin point deficiencies and tuning various parameters for better results. All procedures need to be documented in log sheets, charts and records maintained for every heat. This can achieve certain tangible benefits such as:

- High and steady metal temperature

- Optimum coke consumption
- Steady chemical composition of metal
- Uniform physical properties of metal
- Uniform melting rate

More than 80% of the casting rejections due to blow holes, shrinkage cold shuts, hard spots, undesirable type of graphite and low strength of iron are eliminated by improving operational practices.

4.1.9 Reducing Rejections to Improve Yield

Quality control and design of castings has a direct bearing on coke consumption. Higher rejection rate of castings and lower output to molten metal ratios lose not only in terms of metal loss, but also imply substantial expenditure for reprocessing scrap. This aspect requires the process to be examined, right from sand preparation, moulding, design of gates and risers, melting and pouring practices and control of metal composition. This requires a detailed long-term plan at the shop floor level to improve quality and reduce melting losses besides enhancing productivity of fuel used in the melting operation.

4.1.10 Utilisation of waste flue gases in Cupola

Long Term

An important aspect of cupola operation is the utilisation of waste flue gases in large foundry units of about 5 tonne/hour capacity. Flue gases escaping to atmosphere carry considerable heat, as the gases are at 400 to 500^{0}C temperatures. Recovery of heat can be achieved in a warm blast cupola, by preheating combustion air by waste gas. A recuperator could be designed to capture heat from the flue gases to raise the temperature of the combustion air to 200^{0}C in a warm blast cupola.

In a typical case of warm blast cupola, there was an increase in melting temperature by 15%, resulting in decrease in limestone and secondary flux consumption with substantial reduction in coke consumption. The output of the cupola also increased by about 20%.

4.1.11 PLC System for Cupola Operation

Programmable Logic Control (PLC) systems can control cupola operation and 7store data for subsequent analysis of production and costs. The characteristics of cupola PLC technology for charging and melting and gas for a hot blast cupola are as follows

- The cupola melting installation is operated, controlled and monitored by means of PLC technology from a workstation fitted with video screen.
- The batching and charging installation and the cupola installation with its gas handling equipment are each controlled by a PLC system.
- The charge makeup program controls the batching of the charge materials by magnetic crane or with feeders, according to the pre-set charge mix.
- The variations in the charge mix due to the size of the charge materials are corrected by a number of well proven methods.
- The actual weights of the charged materials, the standard deviation of the charge mix and the extreme values are printed.
- The blast rate and the blast temperature are controlled and monitored, as well as the percentage of oxygen in the top gas.
- By means of the PLC technology the installation can be started and shut down automatically, while all changes of the operational parameters are registered.
- The operational parameters of the installation can be recorded and evaluated using spreadsheets.

4.1.12 Induction Furnace - Capacity and Utilisation Factor

Operational

The specific energy consumption decreases with increase in furnace size, due to the accompanying decrease in surface area-volume ratio and resulting decrease in specific heat losses. The holding power requirement is governed by the time for which the molten metal is maintained at the required temperature. This depends on the furnace utilisation. Holding requirements are also dependent on furnace size. Thus, it is doubly important that smaller furnaces are used with high utilisation factors.

Since mains frequency furnaces need to be operated with molten heel and consume up to 20% more energy on cold starting, the operation of under-utilised furnaces should be analysed for the economy of continuous operation or cold starting after set intervals of a week or fortnight.

4.1.13 Induction Furnace - Refractory Lining

Operational

The lining thickness of most furnaces is decided based on the experience of the operating personnel. Heat losses through the walls can be as high as 60% of the total losses. But, refractory thickness cannot be increased solely on this basis, as it also affects the power factor and electrical efficiency, due to variations in reluctance between the coil and the charge. Insulation thickness can be judiciously increased for attractive payback periods.

4.1.14 Electrical Losses and Power Factor Improvement

Medium Term

In induction furnaces, the current carried by the conductors is high. Substantial savings in I^2R losses in cables are feasible by increase in conductor size, conductor material and power factor improvement.

4.1.15 Induction Furnace - Charge Raw Materials

Operational

The condition of the furnace charge material can result in increased melting time, by restricting the induction effect and limiting the amount of power that can be drawn. Loose scrap or scrap with higher concentration of impurities will restrict the point to point contact. Moisture in scrap, apart from being an operational hazard, also picks up heat of evaporation.

4.1.16 Induction Furnace Lid and Charging

Operational

The furnace lid needs to be opened every time the furnace is charged. Enormous heat losses occur, if the molten metal is exposed. Any delays in charging of low bulk density scrap or failure to close the furnace lid result in lower furnace efficiencies.

4.1.17 Control of Metal Temperature in Induction Furnace

Operational

Unnecessarily high tapping temperatures lead to higher energy consumption, longer cycle time and quicker refractory erosion. The type of charge and castings determines the tapping temperature. The metal is superheated to compensate for heat losses in transfer of metal from furnace to the ladle, ladle movement and transfer of metal from the ladle to the castings. If the material is to be held in the furnace for long periods, due to improper co-ordination between the melting and casting shops or due to non-availability of ladles, the energy losses increase radically.

4.1.18 De-slagging of Induction Furnace

Operational

The removal of slag is a practice, which meticulously practised, can result in substantial energy conservation. The continuous removal of slag before each tapping cycle prevents build-up of slag on the furnace walls, which would restrict the output capacity of the furnace and amount of effective power drawn. To counteract this, most furnace operators resort to operation at higher temperatures or occasional high temperature melts to remove the slag from the surface. Both these practices lead to increase in energy losses and must be avoided.

4.1.19 Molten Heel Practice in Induction Furnaces

Operational

Depending on the position of the coils, a molten heel has to be maintained in mains frequency furnaces. The coils normally enclose the lower 60% to 70% of the furnace and to draw full power, the coil portion has to be filled with molten metal. A lower heel maintenance practice means longer melting cycles leading to higher specific power consumption.

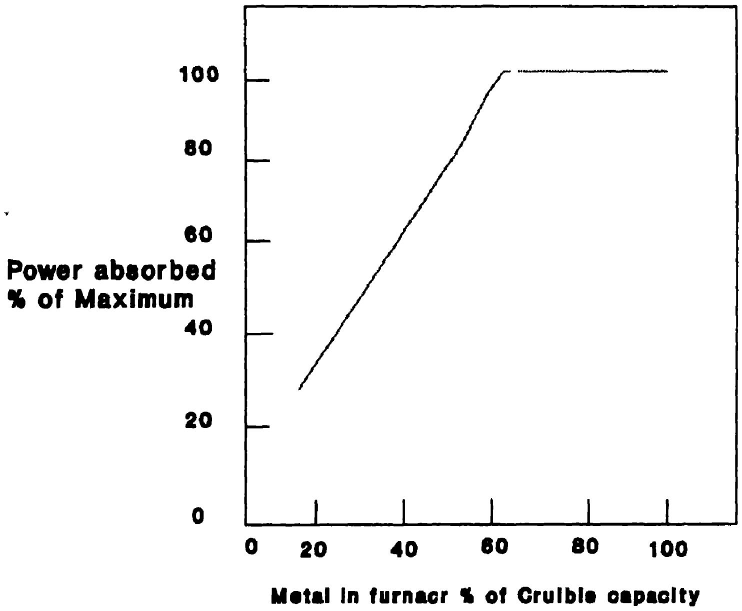


Fig. 4.3 : Power Absorbed vs. Metal in Crucible for Core-less Furnace

Even for medium frequency furnaces operating in the range of 200-250 Hz, a 10 to 20% heel practice can help improve furnace efficiency. Fig. 4.3 shows the relation between power absorbed and metal held in the crucible of a mains-frequency core-less furnace.

4.1.20 Induction Furnace Tapping

Tapping is done with power off. In order to loose as little time as possible, ladles should be ready and waiting. For all practical purposes, furnaces should not be tapped more than five times per hour in order to arrive at a reasonable utilisation factor. If more taps are made, a multiple furnace system or a holding furnace should be installed to reduce the number of taps per furnace per hour. For a 3-tonne furnace, the throughput figures for different idling periods will be:

Idling period per hour	6 min	12 min	18 min
Approx. throughput, % rates	85	70	55
Approx. energy consumption kWh/t.	580	590	605

4.1.21 Medium Frequency Core-less Induction Furnaces:

Application of solid state converter technology has developed these types of furnaces as primary melting furnaces. Further technological innovations in these furnaces, combined with switch-over crucibles and automated charge handling system have increased the productivity and energy efficiency.

The use of a core-less induction furnace is gaining popularity abroad. These furnaces can achieve a higher melting rate, with accurate temperature control and minimal contamination of charge. The level of emissions from the furnaces is also low, although dependent on the purity of charge.

A typical induction furnace is said to have a specific energy consumption of about 600 - 800 kWh/tonne. Considering the theoretical energy required to melt cast iron and raise its temperature to 1450^{0}C is around 380 kWh/tonne, the overall thermal efficiency of the induction furnace will be around 50%. A typical heat balance for a core-less induction furnace can demonstrate that losses through the refractory lining and to the water cooling circuit are significant.

4.1.22 Energy Balance of Electric Arc Furnaces (EAFs)

The efficiency of arc furnace operation is primarily dependent on the efficiency melting. A clear picture of the energy use, losses and gains in the process can be obtained by drawing up an energy balance for the EAF. Before preparing the energy balance, a material balance for the furnace needs to be established. Inputs for the material balance include charge, graphite electrodes, limestone or calcined lime, coke, oxygen and alloying constituents, while molten metal, scrap and exhaust gases constitute the outputs. Table 4.4 shows the energy balance for a typical EAF.

Table 4.4 : Typical EAF Energy Balance

Energy Input	%	Energy Output	%
Electrical power	76	Sensible heat in trapped metal	27
Exothermic reaction like decarburisation	20	Sensible heat in molten metal	4
Graphite electrode Oxidation	4	Sensible heat in slag	4
		Sensible heat in refractories	6
		Heat carried away by cooling water	25
		Heat carried away by exhaust gas	24
		Electrode and Electrical Losses	5
		Radiation and Convection Losses	3
		Unaccounted Losses	2
Total	100	Total	100

** Note: Oxy-fuel burners also supply energy though not shown in this chart*

Elimination of delays and getting maximum output rate from the EAF will ensure energy economy in the melting stage. The three most important parameters, which affect the productivity of the arc furnace are tap to tap time (time taken to charge the EAF, melt and refine the scrap and tap molten metal), furnace availability and yield. It is essential that the entire operation of the furnace, furnace preparation and repairs, charging, melting, refining and tapping are all well planned.

4.1.23 Charging of EAF

Operational

The charge should be carefully selected to suit meltdown operations. In alloy steel production, it should result in a melt down bath analysis, close to the customer's product specifications.

Bulk density and scrap sizes have a close relation to the specific energy consumption. The initial charges should always be of maximum density to achieve the required tonnage with minimum recharges after the initial meltdown starts. Each opening of the furnace can increase energy consumption by 8 to 10 kWh/t of material melted.

A charge comprised entirely of heavy scrap is not desirable, because it does not permit shielding of roof and walls during the melt down period to the same extent as a mixed charge of greater volume, thus reducing refractory life.

Scrap segregation into stockpiles of specified grades ensures a consistent and accurate mix for charging. This ensures that any variation in raw material quality does not affect the charge mix.

4.1.24 Melt Down Practice in EAFs

An ideal melt down practice is to achieve heating of charge as evenly as possible from the centre and exposed areas. For this, the electrode should be lowered as close as possible to the charge by push button operations to reduce the time taken to strike the initial arc. The voltage level should be proper to inject enough energy into the arc to allow the electrodes to bore down into the charge, until they approach the heavy scrap at the furnace bottom. This facilitates optimal absorption of arc energy and promotes economic use of power. Rationalisation of melt down practice reduces specific energy consumption - second or third time of scrap charging is normally decided, based on the experience of the melters. It is desirable that, based on the melt, the plant may establish a relationship between kWh consumption and time for different grades of scrap, and accordingly evaluate the time for charging a second or third time.

4.1.25 Regulation of Tapping Temperature in EAF

Operational

Normally, metal temperature is kept about 150 to 200 °C higher than the tapping temperature, to compensate any temperature drop in the process. In operations based on manual control, there is a tendency to keep the temperature much higher. Every 10 °C increase in tapping temperature can increase specific electrical energy consumption by about 19 kWh (at 30% furnace efficiency as is the case during refining). The higher degree of superheat has also other adverse effects on the quality of steel, electrode and refractories consumption. Standards for tapping should be set, based on a study of temperature drops at various levels for different steel grades.

4.1.26 Electric Arc Furnace Lid and Charging

Operational

The EAF lid has to be opened every time the furnace is charged. Enormous heat losses occur of the molten metals exposed and any delays in charging of low bulk density scrap or failure to re-close the furnace lid result in decreased furnace efficiencies.

4.1.27 Refractory Lining of EAFs

Operational

Lining thickness of most EAFs are fixed, based on the experience of the operating personnel. Heat losses through walls can be as high as 60% of the total losses. But, the refractory thickness cannot be increased only on this account, as it also affects the power factor and furnace efficiency. After careful examination, insulation thickness can be increased yielding good returns in terms of payback.

4.1.28 EAF Capacity Utilisation Factor

Operational

The specific energy consumption decreases with increase in capacity utilisation. Under-utilisation may be the result of poor availability, due to high maintenance time and process delays, and external factors such as power cuts and interruptions and industrial relations problems. Typical internal delays that affect specific energy consumption, and can be controlled by the plant include:

- Delays in crane service or scrap delivery, shut downs for power demand and mechanical failures.
- Scrap charge of incorrect chemical analysis may effect furnace schedules and melting to a different specification, than the analysis desired due to improper scrap segregation and charge planning.
- Breakage of electrode due to heavy pieces of scrap along the side walls of the furnace falling during melt down, large concentration of charge material such as limestone, while the electrode drive continues to exert downward force as long as current in that leg of the circuit is low.
- Errors in the selection of power input levels may result in slow melting rate and damage the furnace lining and roof.

4.1.29 Efficient Use of Fuel Oil in EAFs

Operational

Furnace oil and LDO are used for arc furnace ladle pre-heating. Savings in fuel consumption can be realised by improving operational practices such as pre-heating the oil, reducing excess air levels, and reducing excess gap between ladle and roof. Other measures suggested to improve fuel efficiency are:

- Installation of slide gate system on ladles in place of conventional stopper rod assemblies requiring replacementafter every heat, reduces fuel and time for ladle pre-heating
- Utilising garnex board with back lining of ramming mass instead of high alumina siliminate bricks deployed in the conventional system for concast machine. This measure can eliminate requirement of furnace oil or LDO for tundish pre-heating.

The combustion equipment is also discussed Annexure 5.

4.1.30 Economies of Scale / Size of EAF

Long Term

The EAFs in India range from 5 to 50 tonne, with an average of 12 tonnes, which is small, compared to developed countries, where EAF units can be even 150 tonne. The advantages of higher capacity furnaces are lower investment cost per tonne output, lower fixed operating costs per tonne of output, marginal lower consumption of power and electrode per unit of output. Furnaces of more than 25 tonne provide greater economy by adopting modernisation measures like scrap pre-heaters, oxy-fuel burners, UHP transformers and greater degree of automation in operations.

4.1.31 Use of Water Cooled Panels and Roofs in EAFs

Operational

The service life of EAF side-walls has been dictated by the high wear rate of the hot spot refractories. These require frequent repair or replacement, while the remaining lining is in good condition. Use of water cooled, side walls and roofs helps to reduce refractory consumption by increasing lining life and reduced thickness of refractory lining. Cost saving of 75% in refractory materials and increase in roof service life of more than 50% have been achieved. The overall availability of the EAF is considerably increased. Long arc melting practice can be carried out, reducing melting time by 5-10 minutes.

4.1.32 Oxygen Lancing in EAF

Operational

Oxygen lancing helps to achieve a uniform temperature distribution by strong agitation of the liquid steel, resulting in reduced melting cycle time. This also serves as a secondary energy input, as a consequence of increased oxidation reaction of carbon. The lance has to be applied at the slag/steel interface to inject oxygen into the bath for decarburisation and into the slag to assist foaming. The quantity of oxygen varies from 15-25 Nm^3 per tonne liquid steel.

4.1.33 Foamy Slag Practice

Operational

In foamy slag practice, oxygen is injected with carbon to form a foamy slag caused by CO gas generation. The slag shields the arc radiation to side-walls and roof, with better thermal efficiency and reduced refractory wear, improved productivity, reduced power and electrode consumption and improved life of side wall panels and roof. However, the slag pot capacity should be sufficient to accommodate lower bulk density slag.

4.1.34 Use of Water- Cooled Chimney in EAFs

Operational

EAFs of 15 tonne and above, using oxygen lancing/foamy slag practice, may consider the installation of water cooled chimney. The chimney helps in exhausting flames and fumes, which normally shoot up from the gap between the electrode and cooler. This will increase electrode life and also facilitate in keeping clean environment at shop floor.

4.1.35 High Power Transformers for EAF Operation

Operational

An Ultra High Power (UHP) transformer ensures high power input rate. Modern high-capacity EAFs have specific transformer capacities exceeding 800 kVA/tonne. High transformer capacity is optimally utilised by separating the refining operation outside the EAF.

This results in better thermal efficiency and quicker melting of solid charge particularly DRI/HBI, thus substantially increasing productivity and reduced power consumption. Saving in power up to 15 kWh/tonne is feasible for large EAFs.

4.1.36 Scrap Preheating

Short/Medium Term

Scrap pre-heating has emerged as the most effective method of waste heat recovery method. Up to 60% of the heat loss by exhaust gases can be recovered resulting a reduction of specific energy consumption by 30-50 kWh/tonne.

The other advantages of scrap preheating are reduced electrode and refractory consumption, arc stability, reduced melting cycle time and lower heat loss. A further development, to substitute electricity with cheaper fuels, is the twin shell furnace with an interchangeable roof and burner cover. In this process, while melting takes place in one shell, the scrap is pre-heated to 800-1000 °C using fuel-fired burners in the other. The exhaust gases from both shells are used to preheat the scrap in a primary scrap pre-heater. Electrical energy savings of 30% are feasible, with a corresponding saving in graphite electrode consumption.

In an EAF, the exhaust gas from the EAF was about 20% of the total energy input. The average flue gas temperature was about 1520°C and during oxygen lowering it was still higher. This exhaust gas could be effectively utilised to preheat the scrap charge to a temperature of about 250°C and the equivalent savings in energy to heat the scrap from 30°C to 250°C is about 1.54 x 10^5 kJ/lt.

4.1.37 Eccentric Bottom Tapping in EAFs

Operational

Eccentric bottom tapping is slag free vessel manipulation tapping system. A valve fitted at the bottom of the furnace controls the tap hole. Tapping is interrupted as soon as slag is detected in the molten stream. This provides good results with residual liquid pool (hot heel) practice.

The furnace side-walls can be covered to about 87%, with water-cooled wall panels. Tapping temperature is reduced by 30°C, and tapping rate is increased, with a compact stream, low gas absorption, clean steel and better lining life, resulting in power saving to the extent of 10 - 15 kWh/tonne.

4.1.38 Oxy Fuel Burners for EAFs

Long Term

Auxiliary burners are used in EAFs to eliminate cold-spots. Non-uniform thermal distribution results in increased power consumption and depends on shell shape, furnace capacity and operational conditions. The burners must be mounted so that any sudden collapse of scrap is avoided.

The location, number and type of burners depend upon the size and shape of the furnace. A sole burner, introduced through the slag door, is directed in turn towards all three cold spots in small and medium EAFs. In bigger EAFs, three separate retractable burners are mounted on the sidewalls, but these are highly susceptible to damage from slag splashes. In order to avoid this, the burners are sometimes mounted on the roof-ring with the arc being fired downwards at a tangent, through the cold spot. Oxy fuel burners are discussed in Annexure 3 in detail.

4.1.39 Plant Layout for EAF Operation

Long Term

The plant layout should ensure a smooth flow of material in the ladles from the furnace to the casting bay. Any delay en-route or a long, circuitous path would increase heat losses. To ensure higher productivity and efficiency, there should be no bottlenecks in various ladle operations such as furnace tapping, ladle treatment, continuous casting, de-slagging and ladle pre-heating.

4.1.40 Submerged Tapping and Liquid Heel in EAFs

Operational

If metallurgical parameters permit the operation of the EAF with a bottom heel of around 15% and slag on top, the Eccentric Bottom Tapping (EBT) furnace offers the following advantages:-

- No slag carryover into the ladle.
- Immediate initiation of metallurgical reactions in next heat, especially if oxygen lancing is also applied.
- Arc stability and higher power input during scrap meltdown.
- Longer service life of bottom refractories, as they are protected from arc during pour down.

- Possibility of tapping at a lower temperature, because of lower oxidation in steel and less heat losses. A ladle weighing system, which can quickly tilt back the furnace, controls the tapping.

4.1.41 Ladle Preheating for EAFs

Operational

Ladle preheating is necessary to ensure proper temperature of metal at the caster, longer life of refractories in the ladle and to avoid presence of moisture in the ladle lining at the time of pouring the molten metal. If the ladle is preheated to a proper temperature, extra heating of the metal in the EAF can be avoided, saving electrical energy. Energy savings in preheating ladle using oil-fired burners can be achieved by:

- Ensuring proper combustion and tuning of the burners
- Close fit between the lid and ladle to bring down flue gas losses
- Proper co-ordination between preheating the ladles and tapping
- Recycling preheated ladles and covering ladles after metal has been conveyed to the casting section
- Use of recuperative burners to tap the heat in flue gases
- Re-circulating flue gases in ladles before pre-heating

Ladle pre-heating is elaborated in Annexure 4.

4.1.42 Loading of Heat Treatment Furnaces

Operational

The loading of a furnace contributes significantly in improving the thermal efficiency of a furnace. In an under-loaded furnace, only a small part of the supplied heat is transferred to the stock, leading to low thermal efficiencies. In an over-loaded furnace, the stock may not be uniformly heated leading to poor quality. In view of these, furnaces should be optimally loaded which can best be obtained by trials.

4.1.43 Excess Air Control of Heat Treatment Furnaces

Operational

The products of combustion, which emit from the furnace, carry kinetic energy as sensible heat. In any combustion process, the aim should be to supply just enough air to completely burn the fuel. The theoretical air to be supplied, which depends on the chemical composition of the fuel, is called the "stoichiomatric air". But, in actual practice, the stoichiometric air is not sufficient to aid complete combustion. Some air is supplied in excess. Higher the excess air, higher will be the sensible heat loss in the flue gases. Obviously, excess air needs to be optimised.

4.1.44 Waste Heat Recovery

Operational

The temperature at which the flue gases leave the furnace is higher than the temperature of the stock heated. About 25 to 40 % of the heat input to the furnace is carried in the flue gas. Higher the flue gas temperature, higher will be the waste heat availability, which can be recovered by any of the following methods:

- Preheating the stock
- Preheating of combustion air
- Installing waste heat boilers

In metallurgical furnaces, one effective use of recovered heat is preheating of the stock. The effectiveness of heating depends on the flue gas temperature, physical and dimensional properties of the stock and the stock handling procedures.

The preheating of combustion air by a recuperator or regenerator is yet another heat recovery method. Substantial savings are achieved by preheating the combustion air.

Waste Heat Boilers (WHBs) operate on the heat available in the flue gases. They are generally considered when the temperature of the flue gases is less than 750^{0}C. Here, the heat transfer is essentially through convection and only the sensible heat in the flue gases is used for converting water to steam. The quantities of flue gases handled by WHB's increase, due to the high heat transfer surfaces to be provided, which, in turn, is because of low heat transfer coefficient temperature difference between the generated steam and flue gases.

4.1.45 Heat Loss from Openings in Heat Treatment Furnace

Operational

Considerable heat losses occur through furnace openings. In certain cases, these can be avoided. The heat losses that take place are proportional to the size of the openings and furnace temperature.

4.1.46 Control of Draught in Heat Treatment Furnaces

Operational

It is very important to maintain proper pressure inside a furnace. It is generally recommended to operate a furnace under slight positive pressure. Negative pressures lead to air infiltration, affecting air fuel ratio and furnace temperatures, with consequent increase in fuel consumption. Excessively positive pressures lead to result in leaping out of flames, overheating of furnace refractors leading to reduced brick life and other associated problems. A reasonable pressure to operate would be about 25 mm wg

4.1.47 Minimising Wall Losses in Heat Treatment Furnaces

Operational

Radiation losses from the furnace walls are quite significant, and more so if the walls are not properly insulated. The use of quality insulating material with appropriate thickness should be considered. Using the surface temperature, exposed area and number of hours of operation, the radiation losses can be computed.

4.1.48 Improved Productivity in Sand conditioning, Moulding and Core Making

Operational

Apart from melting, there have been developments in foundry technology in related areas with an accent on productivity and quality. These have a favourable impact on the specific energy consumption through improvement in plant productivity. These include:

- Development of high pressure moulding, resulting in closer tolerance and better finish and lower rejections of castings.
- Normal moulding machines designed to improve casting accuracy, which run faster. There are machines producing 500 moulds per hour with only one operator.
- Automated pouring, that eliminates human error in pouring the metal into the mould at controlled rate and temperature.
- Development of "lost foam process", which uses polystyrene patterns and eliminates the need for sand binders or mixers or moulding machines. When poured, the pattern evaporates instantly under the heat of molten metal and is replaced with an exact duplicate in metal. This process has many advantages, such as elimination of defects attributed to mould, flexibility in design, elimination of cores and moulding machines.
- Adoption of cold box and other no-bake processes for core making have many benefits like dimensional accuracy, surface finish, quality, productivity, energy conversation and prevention of pollution of working environment.

4.1.49 Shakeout and Reclamation Systems in Casting

Operational

The necessity of stringent controls on casting quality and production costs, along with environmental regulations has resulted in many improvements in foundry operation. Totally enclosed vibrator drum shakeouts have replaced the traditional flat deck, open style shakeout. In the new system dust, heat and noise are more easily controlled, while eliminating damage to surface, due to its gentle vibrating action.

New technologies of recycling sands through elaborate reclaimers are fast becoming a standard practice. These conform to regulations against dumping old sand and result in a cleaner environment. The reclaimer systems available today are wet, thermal, pneumatic and mechanical devices.

4.1.50 Cleaning of castings

Operational

Use of industrial robots and manipulators have resulted in impressive gains in productivity, product quality, reduced costs and better environment. These are used extensively in die-casting and investment casting foundries and to a limited extent in iron steel and foundries.

Application areas include sand slinging/filling, core setting mould spraying, mould venting, general material handling and finishing various operations.

Fettling or cleaning of castings involves dirty, noisy and hot working environment. There is a need to develop automatic fettling systems in foundries and introduction of the necessary safety and health legislation to combat the difficult working conditions.

4.2 Energy Conservation Opportunities in Forging Industry

4.2.1 Heating Furnaces in Forging Industry

Operational

To achieve a uniform temperature gradient inside the furnace chamber, the ratio of length to width should be 2.5 to 3.0. The height of the working chamber should be just sufficient to allow proper circulation of the products of combustion above the stock being heated.

As the heat in the furnace is transmitted to the stock mainly by radiation, for maximum coefficient of heat transfer to the stock, the ratio between total surface area of stock and inside furnace walls and roof is generally designed at 0.25 to

0.3. The height of the heating units varies from 800 to 1600 mm and cross section of exhaust gas flues is designed to obtain a gas velocity of 2-3 m/sec.

In a forge shop, stocks are heated and soaked in the furnace to temperatures up to 1250°C. The furnace temperature is normally maintained 50 - 100°C higher than the maximum forging temperature of the stock. The working chamber is generally maintained at a temperature of 1300-1350°C, depending upon the steel to be heated. The hearth dimensions depend on the maximum size of materials to be charged and the desired furnace productivity.

Proper selection of heating furnace for any forging equipment is important for optimum utilisation. Any increase in heating capacity of the furnace will not result in higher production, because of the limited capacity of the forging equipment, but will increase fuel consumption, which is not desirable.

Table 4.5 suggests the desirable size of furnace for optimum production of various forging equipment.

Table 4.5 : Hearth Size for Various Forging Equipment

Forging Equipment	Hammer/Press capacity (t)	Hearth area (m^2)
Forging hammer		
	0.15	0.50
	0.40	0.70
	0.75	0.90
	1	1.20
	2	4.50
	3	6
	5	12
Forging press		
	800	23
	1000	26
	1250	36
	2000	50

Heat Treatment in Forging Industry

The process of heat treatment is determined by the metallurgical structure and the mechanical properties desired in the forged part. Small heat treatment furnaces are similar in design and construction to the small heating furnaces provided in the forge shops except that the optimum temperature of chamber is limited to 1200°C. Bigger furnaces are of box type with removable bottom. These furnaces should be capable of developing maximum chamber temperature of 1200°C. Two rows of fuel burners are generally installed on each side of furnace at a distance of 400 to 1200 mm for proper distribution of products of combustion and obtaining uniformity of temperature within +/- 5%.

4.2.2 Optimisation of Fuel Utilisation in Forging

Operational

Fuel burners employed in the heating and heat treatment furnaces are of low-pressure type. Excess air in the fuel / air mix should not exceed 10-15 percent of the theoretical air required for complete combustion.

Any increase in excess air supply lowers the overall efficiency of the system. For supplying the right quantity of fuel and air, the furnace needs to be provided with measuring and control instruments. With proper burner-control instrumentation, fuel savings up to 5% could be possible.

Most burners used in forge furnaces transfer heat to bar stock by radiation. However, a few burners have been developed, wherein the heat transfer takes place by convection. This results in more rapid heat transfer and higher efficiency. Such burners are available for application with gas or light distillate oils only. These burners are discussed more in detail in Appendix 6.

4.2.3 Waste Heat Recovery in Forging Industry

Long Term

In a conventional furnace, almost 65% of heat input is carried away by the flue gases without doing any useful work. If flue gases are made to heat the combustion air, 15% to 20% oil savings can be effected. This is achieved by an appropriate recuperator system.

In forging furnaces, recuperators have been installed between furnace and stack to utilise the heat in the outgoing products of combustion for preheating the air supplied for combustion. The pre-heated air at 400-500°C raises the temperature of combustion, improves furnace efficiency and results in reduced fuel consumption.

Metallic recuperators are normally selected for heating combustion air up to 400°C. Table 4.6 gives a few technical characteristics of such recuperators

Table 4.6 : Characteristics of Recuperators

Parameter	Value
Type of flow	Direct cross flow
Temp. of combustion	1200°C
Temp. of heated air	400-500°C
Temp of combustion	800-850°C
Products at recuperator outlet	
Air velocity	5 m/s
Velocity of exhaust gases	0.8-2 m/s
Overall co-eff. of heat transfer	15-20 kcal/m^2.k.h
Resistance of air flow	90-110 mmwc
Resistance to flow of exhaust gases	0.6 - 1.0 mmwc

The surface area of recuperators provided for heating furnaces usually varies from 4.0 to 5.5 m^2/ m^2 of hearth area. Table 4.7 gives the recuperator surface area for various heating furnaces.

Table 4.7 : Recuperator Surface Area for Various Heating Furnaces

Furnace Hearth Area (m^2)	Recuperator Surface Area (m^2)
0.7	3
1.2	6
2.5	12
5.6	30
10.4	55

4.2.4 Effective Maintenance Practice in Forging Industry

Operational

Effective plant and equipment maintenance practice is another important factor in improving productivity since the industry being highly capital intensive, combined with the self-destructive nature of major equipment, due to process peculiarities. Some indications of maintenance, or rather the lack of it, are scaling, which would result in poor heat transfer, leakage in airflow and defective insulation leading to radiation losses.

In view of the significance of proper raw material quality, die-steel material, for the performance in forging in terms of yield and productivity, it is desirable that the industry adopts consistency in these areas.

Some new technological innovations in the forging industry are discussed in Annexure 6.

4.3 Energy Conservation Opportunities in Utilities

4.3.1 Compressors

Electricity is the major energy source for compressors. Even a small saving, which is feasible even in a well-managed system, is worthwhile. Areas of emphasis for energy efficiency in the generation, distribution and utilisation of compressed air have been highlighted here.

A compressed air system normally consists of air compressors with filters, coolers and dryers, air receivers, motor and drive transmission and a distribution system.

During compression, power supplied to the shaft is used to increase the internal energy of the air by increasing its pressure and temperature. If air temperature is reduced to its intake temperature, between stages, the compression is isothermal otherwise, it is known as adiabatic compression. The former consumes less power.

The energy audit of a compressor system aims to explore various possibilities of conservation, estimating compressor efficiency, free air delivery capacity and other energy related aspects. The tests to be carried out periodically, to ensure maximum efficiency of the system, are Free Air Delivery (FAD) tests, quantification of compressed air leakage and pressure drop in air distribution network

The basic aspect of energy conservation is the selection of the right compressors. Often compressors are selected based on initial cost, not lifetime cost comprising the fixed and variable costs such as energy, maintenance and supervision cost. Some points to be considered when selecting a compressor include single or multi-stage compressors, capacity utilisation and efficiency.

During no load, reciprocating compressors consume about 10 to 12 percent of the full load power, where as screw compressors consume only about 60 to 75 percent. Screw and centrifugal compressors are suitable for base or full load applications but are not desirable for part load applications, where slide vane or inlet guide vane controls are used, which invariably increase the specific energy consumption.

The location of air compressors within the building can have a significant bearing on the amount of energy used by the compressor in view of the intake air temperature, dust and moisture content of the atmosphere.

Most industrial compressors are water cooled, where the heat of compression is removed by circulating cold water to cylinder heads, inter coolers and after coolers. The resultant warm water is cooled in a cooling tower and circulated back to the compressors. The temperature and quality (TDS) of cooling water also effect the efficiency of the compressor.

The inter-coolers and after-coolers in a multistage compressor cool the air between two stages and remove excess water from the compressed air. Ideally, the temperature of the inlet air at each stage of a multi-stage machine should be the same as it was on entering the first stage. This is referred to as "perfect cooling". But in actual practice, because of fouled heat exchangers caused by scaling of dissolved solids in cooling water, the inlet air temperature to subsequent stages is higher than normal levels, resulting in higher power consumption. Use of cold water reduces power consumption. However, very cold water can condense the moisture in air, leading to cylinder damage.

After generating compressed air, it has to be conditioned to remove oil, moisture and dirt, and transported to end user points without significant pressure drop either by a ring or semi-ring main system. Generally, ring main is the best arrangement for a compressed air system. It also makes the alteration and extension of the existing system easier.

If the resultant power wastage were fully appreciated, it is evident that any expenditure on sealing leaks could be easily recovered in energy savings. Various checks and inspections are recommended for the efficient operation of compressors.

A few pertinent conservation measures include:

- **Reducing Pressure Settings**

[illegible]

This is an important aspect, which is often ignored in practice. It directly tents to reduce the loading time.

- **Reducing Compressed Air Usage**

House-keeping

As a general measure, the practice of using compressed air for mundane uses such as body cleaning must be discouraged.

- **Arresting Leakage**

Short/ Medium Term

Better maintenance practices and regular inspection are necessary to avoid leakage of compressed air, which can be an undetected source of power wastage.

- **Capacity Control**

Medium Term

With the availability of state-of-art variable speed drives, energy consumption can be controlled.

- **Selection of Compressors**

Long Term

A proper selection of single or multi-stage compressors, considering the capacity utilisation and efficiency would substantially reduce the energy consumption.

- **Pipeline Design**

Long Term

Layout and location of a compressor, with optimum pipelines, can definitely be an asset.

4.3.2 Blowers

In the Foundry and Forge industry, blowers are used for combustion air in the furnaces. There can be a great potential to conserve energy by measures such as retrofitting of speed control device, replacement of inefficient blowers, marginal modifications, reducing system losses, minimising leakage and avoiding redundant ducting.

Computing the existing efficiency of a blower and comparing it with that guaranteed by the manufacturers can identify problem areas such as motor,

motor coupling, ducting or system. Blowers normally work at constant speed and perform economically over a very narrow range near design point. Even a small variation of the working point from the design point results in an unnecessarily high energy consumption.

Mechanical throttle devices are used to regulate the flow, but as they offer mechanical resistance to the flow, they consume a large amount of energy. A more effective way to regulate the flow and improve overall efficiency of the system is by replacing mechanical throttling devices by variable speed control of blower motor. Control of suction air by motor frequency control and a guide vane is also an effective method of regulating flow. Since flow rate is proportional to blower speed and power consumption is proportional to the cube of the speed, substantial power savings are expected even for a small decrease in flow rate.

A damper can control the blower air discharge. However, this also wastes electrical energy in overcoming the friction introduced in the flow by closing the damper. This can be avoided by a variable speed drive to control motor speed and thus, blower discharge.

A few simple energy conservation measures include:

- **Avoiding Unnecessary Operation of Blowers**

Operational

This is a mere routine, and is a direct result of better operating practices.

- **Avoiding Rise in Blower Static Pressure**

Short Term

Very often, it is observed that it is possible to achieve the same output at a lower pressure, effecting considerable savings.

- **Variable Speed Drives / Couplings**

Medium Term

Conventionally, dampers have been used to regulate the flow of compressed air. With their high friction and wear and tear, they are a prime suspect where higher energy consumption is recorded. Variable speed drives and couplings can be effectively used to replace dampers to regulate the flow. The replacement is an easy retrofit and can effect substantial savings.

- **Replacement of Low Efficiency Blowers by High Efficiency Ones**

Medium Term

As technology develops, high efficiency equipment are gradually replacing the older and more outdated equipment. This is the case with blowers also, where a number of high-efficiency blowers are available as retrofits on the existing system.

4.3.3 Motors and Drives

Motors should be chosen considering machine load at start and during running. The annual cost of electrical energy consumed by a motor is 2-3 times the initial cost of the motor itself. This emphasises the need for choosing energy efficient motors, even if they are slightly more expensive. The energy consumption in motors is based on the efficiency of the driven equipment and the system. One of the main reasons for inefficiency is routine under-loading. Often, high capacity motors are selected to meet initial torque requirements.

Table 4.8 : Savings from higher efficiency motors (rating 20 HP/14.9 kW)

Parameters	$\eta = 87\%$	$\eta = 93\%$
Initial cost (Rs.)	24000	32000
Annual capital charges @ 20% for 10 years life	4800	6400
Input power (kW)	17.15	16.04
Power consumption/year in units (8000 h)	137200	128320
Electrical charges @ Rs. 4/- per unit	548800	513280
Total recurring cost (Rs.)	553600	519680
Total savings/year (Rs.)	-	33920

Most motor driven equipment such as fans, pumps and compressors are subjected to varying load. These systems are designed for a maximum duty condition that rarely occurs, with the result that they run for long periods at less than maximum flow. The reduction in flow is achieved by dampers, throttle valves or by-pass systems, all of which are energy-inefficient. Substantial savings can be made if the system is altered, so that control is achieved by varying the speed of the motor instead.

Relevant conservation measures for the motors and drives include:

(a) Proper Loading of Motors

Medium Term

Soft starters and energy savers avoid the selection of high capacity motors. Soft starters are solid-state electronic components, which control input voltage according to starting torque required for the driven equipment, resulting in smoother starting of motors by drawing lower current. The high instantaneous current at start is avoided. Energy savers also control voltage and current according to the load. They are most economical in motors, loaded less than 50 % for more than 12 hours a day.

(b) High Efficiency Motors

Medium Term

The cheapest motor does not imply the least expensive one. Running costs must be considered with capital cost when selecting a motor. Motors that drive fans, compressors and pumps, where variation in throughput is required continuously, can be replaced by high efficiency motors to reduce energy intensity. These may weigh a little more, be slightly larger in dimension and cost about 30 % more. However, as they consume less power, the extra cost is soon recovered. Their higher PF implies less expenditure on power factor correction equipment.

(c) Motor Protection Relays:

Medium Term

For important and strategic motors, it is advisable to use motor protection relay to avoid motor burning, which could prove costly both in terms of loss of motor as well as production downtime.

4.3.4 Electricity Supply System

The use of energy efficient electrical equipment coupled with improved operating practices helps to control losses in distribution and equipment. Reduction in maximum demand load, based on improved equipment demand control, power factor correction and improvement, energy efficient motor selection and utilisation, and improved lighting practices can result in an overall reduction in electricity consumption by 5 - 10%.

Integrated load management can effectively control maximum demand, especially during peak periods of the power system. Higher voltage results in lower line current and losses. It is necessary to maintain standard voltage levels by rationalising tap positions of transformers. This would also minimise energy losses in cables and bus bars. Cable/Line losses are the sum of I^2R or resistance losses. Resistance is inversely proportional to cross sectional area of conductor and hence, higher the cable size, lesser would be the energy loss. If cable size is inadequate, it is advisable to either replace it with higher size cable or provide additional circuits depending on the field conditions.

Power factor (PF) is the ratio of actual power in kilowatts to apparent power drawn from the line in kVA. Improvement in PF facilitates better utilisation of existing capacity and some reduction in resistance line losses. The higher the PF, better is the electricity use. PF can be improved by using capacitors, synchronous motors, synchronous condensers and other high PF equipment in series with the load.

Some energy conservation measures in the electricity supply system are:

(a) Load Management and Maximum Demand Control

Short Term

Electricity demand and supply should match instantaneously. This needs reserve capacities to meet peak demands. The cost of peak demand is normally referred to as demand charge. In India, at present, demand charges do not fully reflect the marginal costs. A review of tariff revisions indicates tendencies to hike demand charges and introduce time-of-the-day metering. As such, there is a need for integrated load management to effectively control maximum demand, especially during peak periods of the power system.

(b) Staggered Running of Motors

Short Term

When running large capacity motors, it is advisable to stagger running of these motors, where feasible, with a suitable time delay, as the process may permit, to minimise the simultaneous maximum demand depending on conditions.

(c) Shedding Non Essential Loads

Short Term

When maximum demand tends to exceed a pre-set limit, shedding non-essential loads temporarily can restrict it. It is possible to install direct demand monitoring systems, which will switch off non-essential loads when a pre-set demand is reached. Simple systems give an alarm, and the loads are shed manually.

(d) Power Factor Improvement

Short Term

Due to inductance within a system, the current lags the voltage by an angle, the cosine of which is the power factor. Some methods of PF improvement include:

Use of capacitors - Capacitors in unit modules can be combined to provide the required capacitance when installed at inductive load terminals.

Use of synchronous motors instead of, or along with induction motors, since their characteristics facilitate operation at unity or leading PF.

Use of synchronous condenser, which is a rotating equipment, similar to a synchronous motor. This drives no load, but merely functions to improve PF.

Use of high PF equipment (high PF lighting, ballast) and electric resistance devices (boiler, furnaces) and operation of equipment at near full load.

(e) Minimising Cable / Line and Busbar Losses

Short / Medium Term

Measures for minimising energy losses in the distribution system include proper sizing of cables and busbars and rationalisation of tap positions of transformers

4.3.5 Lighting System

An energy audit of the lighting system will reveal the efficiency of the existing system. Although lighting contributes very little to the overall energy profile, this is also an area of little attention and consequently, the most neglect. The various energy conservation measures applicable for lighting systems are discussed in this section.

Low efficiency incandescent and fluorescent lamps such as tungsten filament lamps (GLS) can be replaced by fluorescent lamps or high-pressure mercury vapour lamps (HPMV) or by high-pressure sodium vapour lamps (HPSV). Where it is difficult to change from incandescent lamps to more efficient lamps (HPMV or HPSV), the blended light lamps (MLL) provide an interesting alternative with no additional investment, as they are a plug-in replacement. The most common way of comparing light sources is to compare their efficiencies defined as output luminous flux (lumens) over the power input (kW).

Most discharge lamps display a gradual reduction in light output over the years. These should be replaced at the end of their economic life even if they do not fail. More supplementary lights, e.g., twin tube luminaires should be provided in the region further from the windows and less supplementary lights, e.g., single tube luminaires near the windows. A 1 m reduction in height of the ceiling can reduce 20-30% energy consumption by way of lower lighting requirement. Painting walls and ceiling with light colours can reduce artificial light requirements. Unnecessary lamps can be removed or switched off, preferably by a timer switch. Natural light can be effectively used by providing large fibreglass skylights and high openings in the walls. Periodic cleaning of lamps and windowpanes will ensure full utilisation of daylight and artificial lights.

A slight reduction in operating voltage, in case of fluorescent tubes, would result in savings without affecting lighting levels appreciably. A separate voltage regulator, which supplies about 380/390 volts to the lighting circuit, be used. In large/medium scale industries, where the lighting consumption is high, it would be economically viable and technically feasible to have a separate 11 kV/240V – 3 phase transformer, exclusively for lighting circuits. Scheduling controls help eliminate unnecessary use of lighting. Timed switching controls ensure lighting systems are turned off, according to an established schedule. These devices range from simple timers to programmable sweep systems.

Some effective ways of conserving energy in lighting include:

(a) Standard Operating Routines:

There should be a "Switch Off" campaign or installation of automatic switching or dimming equipment. The use of local switches for both lamps and fans should be encouraged. This will enable control of lighting near the source itself.

(b) Daylight Conservation:

Use daytime more effectively.

(c) Maintenance Measures:

It is worthwhile maintaining a regular cleaning schedule for all lamps and fittings. This will ensure that optimal light availability is maintained.

Section 5 : Case Studies

5.1 Waste Heat Recovery from Hot Air Venting from FD Cooler

In a specific case, from the material balance of the EAF, the water equivalent of the coke moisture of 7.5% was 260 kg. The energy for vaporisation of this water is taken from the bath to dry it to equivalent coke moisture content of 2%.

Moisture evaporated $= \frac{7.5 - 2.0}{100} \times 3460 = 190$ kg.

$(3460 \text{ kg} \approx 260 \text{ kg} \times \frac{100}{7.5}$

It is clear from the energy balance that heat in bath (slag + metal) forms 65% of electrical power input.

Latent heat of vaporisation = 583 kcal/kg

Heat required to evaporate 190 kg of water = 190 X 583 kcal

Energy savings per heat from latent heat of vaporisation not drawn from the bath $= \frac{190 \times 583}{0.65}$

= 170415.4 kcal

= 198.1 kWh

∴ Annual savings @ 10 heats/day and 300 days/year = 5.94 lakh kWh

This heat can be obtained by waste heat recovery of the hot air venting from the FD cooler. Approximately three tonnes of ferro-alloys and fluxes are added in the ladle in each heat.

Assuming that the temperature of these additives can be raised by 30°C, and 50 kg of water can be evaporated from the lime addition in LRF, the heat in metal and slag in the ladle can substitute 31.1% of electrical power input.

Energy savings/heat $= 3000 \times 30 \times 0.16 + \frac{50 \times 583}{0.31}$

= 108432 kcal

= 126.1 kWh

Annual savings @ 10 heats/day and 300 days/year = 3.78 lakh kWh

Total annual savings = 9.72 lakh kWh

= Rs. 24.3 lakh

Total heat required for heating and drying = 154320 kcal

Assuming Δt of 5°C in hot air,

Heat available per hour in hot air = 248670 X 1.29 X 0.21 X 5

= 336823.5 kcal

∴ Heat available in hot air is more than the calculated requirement of heat energy and hence sufficient.

It is estimated that an investment of Rs.35.0 lakhs would be required to fabricate the insulated duct and heating chamber.

Simple payback period = 1.44 years

5.2 Charge Composition Affects Energy Savings

A foundry unit with an annual production of 5000 tonnes has two 4-T arc furnaces. Charging the furnace with material of unknown composition results in wide variation in opening carbon. This results in increased production costs by way of increased oxygen and higher energy consumption. The company also uses borings and turnings in the EAF charge. Since the density of this charge is very low, the company can save energy by bundling the turnings and borings.

The existing power-on to tap- time is 3.5 hours. It is estimated that, by using a charge of known composition and bundled turnings and borings, the power on to tap time can be reduced by 20 minutes per heat. The annual energy saving for a production of 8600 tonnes of liquid metal at 7 heats per day, 300 days per annum is Rs.8.19 lakh. An investment of Rs.3.5 lakh will have to be made towards purchase of a bundling machine. The payback period works out to five months.

Oxygen Assisted Melting

Use of oxygen assisted melting resulted in reducing the power on to tap time by 30 minutes in one of the units, which in turn resulted in the production of an additional heat per day. In another foundry where oxygen assisted melting was practiced, the plant has achieved a specific energy consumption of 726 kWh with a production of seven heats per day as against 774 kWh without oxygen lancing at a production rate of six heats per day. The lining life with oxygen assisted melting was however reduced marginally. It has also been reported that foundries with severe power cut (of the order of 60%) were using oxygen to the extent of 80-100 cubic metre per tonne to achieve the required production. The lining life was only 60-80 heats in such cases.

5.3 Optimisation of Furnace Operation

A foundry with an annual production of 5000 tonnes of castings has two arc furnaces of 4- T capacity each. By operating both furnaces, around seven heats are tapped per day. It is envisaged that the current production level can be achieved by operating only one furnace with oxygen assisted melting. Oxygen aided melting would result in:

1. Reduction in peak demand.
2. Reduction of specific energy consumption.
3. Additional liquid metal production.

It is estimated that, oxygen aided melting would result in an annual saving of 3,88,000 kWh and the additional production would be around 1350 tonnes. The cost for oxygen would be 4,86,000 and the net savings would be Rs.97,000 per annum. These prices are estimated at prevailing tariffs at the time of the audit.

5.4 Reducing Delays

A foundry producing about 6000 tonnes of good castings per annum has two direct arc furnaces of 5 tonne capacity each. A delay analysis shown below revealed the following:

Nature of Delay	% of Total Heat	kWh/tonne
Electrode Sparking	20	820
Ladle Assembly	4	814
Opening Carbon	4	826
Crane / OCB Failure	7	790
Load Shedding	10	872
M.D. Controller	2	808
Nil Delay	45	724
Other Delays	8	-

Specific consumption without delay = 724 kWh/tonne
Specific consumption with delay = 815 kWh/tonne

The company has been successfully restricting its peak demand through a M.D. Controller. The demand reduction of 400 KVA, which the company has been able to achieve, far outweighs the energy loss due to delays.

The average number of heats per month is 140, of which only 63 (45%) are tapped without any delay. Increasing the nil delay heats from 45% to 70%, about 78 heats can be tapped without any delay. The resultant energy saving due to the additional 35 heats tapped without any delay is 15925 kWh at 5 tonnes of liquid metal per heat. The annual electricity saving would be 1,91,100 kWh, resulting in a monetary saving of Rs. 2,10,210. The investment required would be towards the maintenance of auxiliary equipment.

5.5 Industry Case Study 1

The plant has two EAFs, each with a rated holding capacity of 20/23 Mt. The furnace transformer rating is 12.10/13.55 MVA with 9 taps with off-load tap changer. The molten metal is tapped in a ladle of capacity 20 T through the tapping spout. The furnace has water-cooled side walls and furnace roof. The roof has only three holes for electrodes and the exhaust fumes escape from the electrode openings and slag door. The fumes are extracted through a fume hood.

Operating Practices

The scrap quality is good with a high bulk density and minimal dust, rust and other impurities. The furnace is charged only once during a heat by a charging bucket. Initially, coke and limestone are charged and then scrap is added on top. The roof is then shut and the arc initiated. The electrodes are cooled externally by spraying water on them. Hot heel practice is not followed in the plant.

The specific energy consumption fluctuates between 560 and 730 kWh per Mt. of tapped metal. The electrode consumption is nearly 6.25 kg/Mt. The oxygen consumption is about 250-300 Nm3 / heat.

The arcing period is between 120-140 minutes. This is because, after arcing for 70 minutes at high tap, a molten bath is formed but there is still substantial scrap at the periphery of the furnace. The scrap has to be melted but arcing has to be done at lower tap as the arc becomes naked and higher tap setting would mean excessive loss and heating of roof and wall refractories. The scrap sticking to the sides also poses the problem of suddenly falling into the bath and creating unstable conditions in the furnace.

Another reason for prolonged arcing time is the low voltage received at the furnace. This results in very low rate of energy being released by arcing even at high taps resulting in higher energy consumption. The longer duration of furnace arcing results in more losses as heat is being continuously lost via the cooling water, exhaust fumes and radiation and convection from the furnace shell.

The shell temperatures revealed no excessive losses. Outer surface temperatures were below 60°C on the surface above the slag line and 140°C below the slag line. Refractory consumption is higher due to longer heating and naked arcing.

Specific electrode consumption is also higher particularly because the hot exhaust fumes vent from the three electrode holes and not from a separate fourth hole. This is despite the external electrode cooling arrangement.

An energy balance for the furnace revealed that, on an assumption of 20 tonne of metal tapping at 1710°C in each heat with a power consumption of 13000 kWh, the heat given to metal is nearly 61.6% of the electrical power input. An additional 6.6% heat is given to the slag. Cooling water from the water-cooled cables and armatures carry away nearly 8.5% of the power input. The radiation and convection loss from the furnace shell is only 3.4%. The water-cooled panels contribute 3.1% of equivalent power loss. The remaining 16.7% of power input is lost through hot exhaust fumes, thermal inertia of the furnace and roof, directly radiated out by the arc. Some suggestions for energy conservation included:

Installation of Sidewall Oxy-fuel Burners

EAFs are typically characterised by the presence of cold spots depending on the shell shape, size, capacity and operational conditions. Non-optimal thermal distribution, especially at the periphery of the furnace walls results in non-uniform melting due to temperature difference and sudden collapse of scrap. An energy audit revealed that the scrap charged had a high bulk density, which resulted in scrap near the walls remaining solid even after formation of a molten bath at the centre. From this point of time, after nearly 70 minutes of initiation of arc, the power input to the furnace should be reduced so that the scrap sticking to the sides can gradually slide into the molten bath. The arc becomes exposed and most of the energy radiates to the walls and the roof. The energy for melting the metal sticking to the sides can come only from the bath.

An oxy-fuel burner is used for efficient, rapid melting of scrap by substitution of electrical power with directional heat input from liquid or gas fuels. Oxy-fuel burners should be introduced through the slag door firing across the cold spots to maximise flame to scrap contact. They can also be fixed on the sidewalls or the roof for better access to the cold spots. They can ensure quicker and more uniform meltdown to reduce power consumption by nearly 40 kWh/Mt. of steel produced. The reduced energy demand can be met by using liquid fuel firing oxygen burners.

The initial cost for an arrangement of oxy-fuel burners on both the furnaces would be Rs. 80.0 lakh. The annual energy savings would be Rs. 132 lakh from a power saving of nearly 33 lakh kWh replaced by suitable liquid fuel. The simple payback period is about 8 months.

The biggest advantage is that some of the energy required for the EAFs is met by liquid fuel and consumption of electrical power, a scarce input, is reduced.

Installation of On-line Tap Changer on 66/11 kV Transformers for EAFs

The incoming voltage to the EAF varied between 7.8 to 9 kV, when the grid voltage was low. This resulted in longer heat time in the furnace and higher specific energy consumption. The total energy consumption per heat increased by 1500-2000 kWh for the same quantity of metal tapped. The voltage received on the 66 kV cannot be corrected on the 11 kV secondary of 15 MVA transformers, since the transformers are off-load tap changers.

On-load tap changer should be installed on 66/11 kV, 15 MVA transformers. This will help improve voltage loads received on the primary of the furnace transformers and reduce energy consumption by 2000 kWh per furnace per day. This amounts to an annual energy saving of 12-lakh kWh equivalent to Rs.48 lakh. The investment required is Rs 60 lakh. The simple payback period is 1.25 years.

5.6 Industry Case Study 2

The 50/60 T EAF has been supplied by Demag of Germany. The EAF was originally operating on 100% scrap charge. With the backward integration of a Direct Reduction Plant in the unit, since sponge iron was available, the charge was modified to a mix of scrap and DRI. In early 1993, an experiment was conducted using 100% DRI charge with continuous charging and DRI with 20T-scrap charge.

Since the refractory wear was much more in the 100% DRI heats, in order to repair the refractory lining a furnace shutdown was taken after every 7-8 days of continuos operation. The lining was also patched up by castable magnesia gunniting between heats. The heat immediately after a refractory lining repair or a weekly shutdown had 20 T of scrap charge.

Energy Consumption

Since the charge composition varies, the specific energy consumption also varied between 790 to 850 kWh per MT of billet. The specific energy consumption is higher for a 100% DRI heat by 17% than for a scrap-plus-DRI heat. After a weekly shutdown, the specific energy consumption is about 11% more than a normal 20 T scrap heat but 7% less than a 100% DRI heat. The variation of 2-4% could be attributed to varying percentages of metallisation in DRI, as any unreduced oxide adds to the thermal energy required to melt the charge.

The carbon content in the charge determines the extent of boiling and foaming necessary to cover the naked arc, to enable high power input during continuous charging. DRI is a low-carbon charge, requiring external coke addition to achieve the necessary effect, however, at the expense of higher energy consumption.

The instantaneous power factor to the EAF varied between 0.70 to 0.96. The power factor depends upon the length of arc. Computerised melt control systems are now available in Europe and USA, which maintain optimal PFs by measuring secondary reactance, computing electrical power and energy balances, and controlling the electrode position at a steady-state value. A melt control system would cost approximately Rs. 6.0 crore and savings envisaged are 7-8%. However, this is a long term measure in view of the high investment.

Material Balance

Since only a few of the material inputs and outputs can be measured, the others can be estimated only after establishing a balance. A material balance for a typical heat with 100% DRI charge includes the following:

Inputs: Measured inputs include DRI, calcined lime, coke, burnt dolomite, charge and injected oxygen. Assessed quantities include electrode consumption of 3.774 kgs per MT, refractory erosion quantity based on average thickness of refractory eroded per heat, at 2 mm per heat. Experienced melters can estimate the quantity of molten heel left over from the previous heat and the slag on top of the heel. Compressed air is assessed from actual measured data from the past.

Outputs: Measured outputs include metal tapped, dust in the furnace, velocity of exhaust gases at the break flange and slag. Estimated quantities include molten heel and slag in the furnace after tapping. Since the composition of gases is different before and after the introduction of oxygen lance, the quantities have been separately shown in the balance. About 10% of the exhaust gases escape through the electrode holes and the fifth hole in the roof.

The fourth hole for evacuation of gases and the hole for continuous charging are adjacent to each other. A small amount of charge is sucked into the gas duct and contributes to high dust amount. Around 700 kg of free carbon is evacuated through the exhaust duct and burnt in the After Burning chamber. This contributes to a higher quantity of CO_2 and CO in the gases for measurements taken before the safety damper as compared to quantity of CO_2 and CO at the break flange. The balance is illustrated below.

Input in MT				**Output in MT**			
	Fe_m	**Fe in FeO**	**Fe Total**		**Fe_m**	**Fe in FeO**	**Fe Total**
Hot heel	11.16	-	11.16	Metal tapped	55.53	-	55.53
DRI	49.45	7.38	56.83	Hot heel	9.89	-	9.89
Slag in heel	-	0.22	0.22	Slag	-	2.31	2.31
				Slag in heel	-	0.15	0.15
				Dust	-	0.13	0.13
Total	60.61	7.60	68.21	Total	65.42	2.59	68.01

Energy Balance

On the basis of the material balance an energy balance for the same heat was computed. The temperatures recorded are shown below

Material	Temp in ° C
DRI	70
Burnt Dolomite	28
Coke	26
Char	29
Calcined Lime	38
Ambient Air	29

The metal was tapped at 1605° C. The temperature of the exhaust gases varied between 993 and 1191° C at the break-flange. Water-cooled panels were used for walls, roof and roof elbow to minimise the refractory cost. The flow was measured while temperatures were recorded at 3 minute intervals. The temperature of the soft water in high pressure cooling circuit was simultaneously measured.

The balance remains incomplete as the percentage of unaccounted output energy is nearly 24%, because nearly 1.45 MT of carbon could not be accounted for in the output of the material balance.

The energy balance for the EAF indicated that 29431.1 kWh of electrical power is given to the batch i.e., metal, slag and heel. This is 66.4% of the 44307 of total electrical power supplied to the batch. Heat given to metal tapped is 45.7% of the electrical power input. The detailed energy balance is as below:

Energy Input	kWh	%	Energy Output	kWh	%
Electrical energy	44307.0	72.7	Heat to metal	20237.6	33.2
Oxidation of Electrodes	1671.5	2.7	Heat in slag	8976.0	14.7
Heat of Reactions	15007.4	24.6	Heat to motion heel.	217.5	0.3
			Heat carried away by cooling water in walls.	2638.3	4.3
			Heat carried away by cooling water in roofs	4613.6	7.6
			Heat carried away by cooling water in roof elbow	2065.4	3.4
			Heat carried away by cooling water in high pressure system	574.9	1.0
			Heat carried away by exhaust gases.	5892.7	9.7
			R & C Losses	1208.8	2.0
			Sub-total	46424.8	76.2
			Unaccounted	14561.1	23.8
Total	60985.9	100.0	Total	60985.9	100.0

Certain measures to reduce energy consumption include :

Preventing Overshooting of Boiling Temperatures

Boiling temperatures overshoot tapping temperatures at least twice a day to as high as 1680-1690°C. The outer surface temperatures were recorded with bath temperature at 1664°C and are clearly higher by 20°C. The corresponding surface losses were 10% higher than normal operating conditions. The water-cooling and exhaust gas losses also increased.

Stricter control on boiling temperatures would reduce surface and other losses. The practice of increasing DRI feed rate with abnormally high bath temperatures only taps the excess heat in the bath, but cannot curb the losses.

Since radiation and convection losses are a small percentage of the total energy and the temperatures overshoot, when the heat is nearing completion, the savings are too small to be quantified. Control on boiling temperature would also translate into longer service life of refractories.

5.7 Switching off FD Cooler Fans between Heats

The three FD cooler fans consumed 99.4 kWh and ran continuously for 24 hours, even between heats, when exhaust gas temperatures are much below the maximum permissible temperature of 130°C at the bag filters. Switching on and off of the three fans could be connected with the exhaust gas temperatures of EAF. A thermistor controlled switch could be provided for switching off a fan after the temperature of the exhaust gas falls below a preset value between heats and the fan could be switched on when the temperature rises. A small difference in the temperature settings of the three fans would avoid simultaneous starting of the three fans.

Annual savings of 1.79 lakh kWh or Rs.7.16 lakh are envisaged, at a cost of Rs. 6.0 lakh with a simple payback period of less than one year.

Waste Heat Recovery from Hot air exiting from FD Cooler.

The exhaust gas is cooled to ensure its temperature is below 130°C at bag filter entry by forcing ambient air by FD fans over vertical tubes through which the hot exhaust gases flow. The ambient air, in this cross flow heat exchanger gets heated up and is discharged into the atmosphere.

The flow of air was measured at 2,48,670 m^3/hr at 29°C. The temperature of the hot air at the top and bottom of the outlet of the FD Cooler were measured for a complete heat of 85 minutes in the EAF.

Temperatures Recorded:

Ambient : 29°C

Outlet Air : 33°C before start of heat.

The temperature of the air at the bottom outlet point rose to 49.6°C and then to 79.1°C after 5 minutes and 8 minutes respectively of starting the heat. The temperature at the top and bottom of the FD cooler were 56.5 and 88.2°C respectively.

The temperature of the hot air at the top varied between 127.8°C and 250.5°C for the remaining period of heat and at the bottom between 110.8°C and 173.1°C. The minimum and maximum temperature variations coincide for both points, as these are dependent on the temperature of the exhaust gases. The average temperature of the hot air can thus be calculated from the mean temperature of these two points as 119.3°C and 211.8°C respectively for a period of 75 minutes. In fact, even after 12 minutes of heat being over, the average temperature of the hot air was 106.2°C.

The hot air from the FD cooler can be used for drying coke charged into the EAF. Most ferro-alloys and fluxes added to the LHF pick up moisture from the ambient, which can also be dried by the hot air.

This required an insulated duct to be designed and installed for collecting hot air emanating from the FD cooler, to be fed into drying chambers where it is to be passed over the material to be dried. The saving estimated is Rs. 43.4 lakh with an investment of Rs. 56.0 lakh for a simple payback of 1 year 4 months.

5.8 Increasing the Effectiveness of Recuperator of Billet Re-heating Furnace

The measured combustion air temperature at outlet of the recuperator was 250°C as against the designed temperature of 380°C. This mainly due to soot formation or due to air infiltration. Hence it is necessary to clean the tube surfaces of the recuperator and avoid air infiltration.

The energy audit team felt that, even after rectifying the recuperator, if the combustion air temperature does not raise up to 380°C, possibility of increasing the heat transfer area in the recuperator should be looked into.

If increasing the heat transfer area is not possible, then it is felt that it is economically feasible to go in for a new recuperator where combustion air can be preheated above 400°C. This measure can be implemented only if the burners can handle air temperature over 400°C. Investment considered for improving effectiveness by increasing the heat transfer area in the existing recuperator is Rs.25 lakh.

5.9 Industry Case Study 3

The plant is situated in the Southern India. The main activities in this division are casting and forging of different metal / alloy products. Good infrastructural facilities have been provided for handling metals / alloys for melting, casting, heat treatment and forging. Foundry activities is divided into three different departments like ferrous, non-ferrous and special alloy. Forge department handles the forging of the products of different alloys.

There are eight core less type of induction furnaces of capacities of 50 kg to 1000 kg.

Provision of the third mould : The crucible for molten metal has a capacity to fill 3 moulds at a time, while only two moulds are available. Thus, there was a waiting time of 20 minutes before one of the moulds in which the metal is put gets released for the third pour from crucible. During this waiting period the furnace has to be maintained at 200 kW, to keep the metal in molten condition. An annual energy saving of 32,000 kWh was estimated with a simple payback period of less than one year.

Reducing waiting time of molten metal: The molten metal before being poured into moulds had to wait for about 20 minutes for the spectroscopic analysis in the laboratory. This time can easily be reduced to 10 minutes by proper coordination which could save electricity use during the waiting period by half. The annual energy saving of 16,000 kWh was estimated without any investment.

Covering the crucible during the final melting: During the melting process, the crucible was not covered and considerable heat was lost from the 900 °C molten metal due to radiation. It was suggested to cover the crucible atleast during final melting process with the lid already provided for that purpose. An annual energy saving of 6000 kWh was estimated without any investment.

Closing the top openings: The top openings of the non-ferrous foundry-90 kg induction furnace crucible were covered during the operation. It was suggested to close the opening with a lid to prevent the heat loss. An annual energy saving of about 4500 kWh was estimated without any investment.

Placing moulds closer to the furnace: The molten metal was carried through the other end of the hanger where the moulds were placed. This arrangement called for an additional heating of the molten metal to 700 °C to take care of temperature drop during transfer to keep it in molten condition just before pouring. The actual temperature required at the time of pouring is only 660 °C. This loss due to extra heating of melt could be avoided if the moulds are placed closer to the furnace. An annual energy saving of 13500 kWh was estimated without any investment.

The plant has about 35 different types of resistance furnaces / ovens. All the furnaces are provided with automated temperature control with trip facility as soon as the desired temperature is achieved. It was observed that some of the furnaces were not loaded to the full capacity leading to wastage of energy. If the full loading was not possible it was suggested that the furnaces could be divided into three zones by using vertical type separators with independent heating elements for each zone.

Use of recuperative burners: The four batch furnaces in alloy fabrication consume most of the LDO in the foundry and forge division. The furnace openings are open and the exhaust gases escape through the hood. No arrangement is made at present to recover heat from the waste gases. The British Gas Association has proved that such batch furnaces have an efficiency of only 10%. 70% of the heat generated in the batch furnaces is lost in flue gas. By the use of recuperative burners savings of 30% in the present fuel consumption can be achieved. The total fuel consumed by alloy fabrication per year is 96,000 litres of LDO. The cost of recuperative burner for each furnace in alloy fabrication is Rs.1,00,000. The annual energy saving is Rs.1,40,000 with a pay back period of 2.6 years.

Proper combustion of lead furnace in alloy fabrication: The lead furnace is used to melt 700 kg of lead alloy in a single melt. The average melting time is 2 hours. There are three such melts in a month. The LDO consumption is 100 liters/melt. The combustion analysis was conducted on the flue gas from the lead furnace. The combustion was highly inefficient with a lot of carbon soot indicating improper combustion. Also, the burner alignment was not proper at the bottom of the furnace. The flame was projecting out instead of actually providing heat to the furnace. By proper positioning of the burner and by adjusting the air fuel rate such that soot formation is avoided 25% of the total oil consumption can be saved. The annual saving of 900 litres of LDO can quantify to Rs. 4500/-

Replacing compressed air with blower air: Compressed air is very expensive. For high volume, low-pressure applications such as agitation, air supply to burner blower air should be sufficient. The cost of the blower and the connection lines from the blower to the burner will cost Rs. 40,000/-.

5.10 Industry Case Study 4

A Western India manufacturer of various SG and MS/Alloy castings for automobile industry and railways has a capacity to produce 350 tonne per month SG iron castings and 100 tonne per month of alloy castings. Electric Motors of 1.5 HP to 125 HP are employed for drives of plant and utilities to operate

- Belt conveyors
- Air compressors

- Cooling water pumps
- Centrifugal liners for casting
- Jobbing machines

It is recommended to replace motors, which are old and rewound with high efficiency motors. The cost of high efficiency motors is 30 to 40% more than the standard motors. A summary of energy savings and cost benefit analysis is given below. This can save energy to the tune of 11390 kWh/year (i.e., Rs 33260/-) with a simple payback of 2 years.

Application	Present Drive kW	High Eff. Motor kW	Operating hours	Annual savings Rs.	Installation cost Rs.	Payback period Years
Exhaust Blower	18.50	18.50	7200	15616	27560	1.76
Centrifugal Liner	11.00	11.00	2400	2424	16400	6.76
Sand mixer	15.00	15.00	7200	15220	20410	1.34

Use of Soft Starter for Scrap Bundling Machine

The 22 kW scrap bundling machine operates at variable load. The load on each cycle varies between 1.74 kW to 4.45 kW, while PF varies between 0.25 to 0.5. Soft starter senses the motor load and accordingly controls the magnitude of input voltage to motor terminal. The magnitude of losses within the motor are reduced by improving the operating P.F. and efficiency irrespective of load. This can save energy to the extent of 2615 kWh/year (i.e., Rs 7636/-) with a simple payback of 3.92 years.

5.11 Replacing Refractory Bricks with Ceramic Fibre Blanket

In a foundry unit situated in Western India, manufacture various SG and MS/Alloy castings for automobile industry. The plant has the capacity 350 tonnes per month of SG iron castings and 100 tonnes per month Alloy castings.

At present, the furnaces are provided with refractory bricks on the hot face. During the heat balance trials, it was revealed that the surface temperatures are on the higher side.

Replacing the refractory bricks can bring down the surface temperatures and hence surface losses by ceramic fibre blanket, since the thermal conductivity of the ceramic fibre blanket is lower compared to refractory bricks.

The new surface temperatures after replacement with ceramic fibre blanket of thickness 20 mm was arrived by interpolation after equating the surface losses and conduction losses. The table below gives the summary of the same.

Furnace	**Before replacement**		**After replacement**		*** Savings kcal/hr**
	Avg. surface Temp °C	**Heat loss kcal/hr**	**Avg. surface Temp °C**	**Heat loss kcal/hr**	
A2	78.38	4504.74	59.89	2462.2	1633
B3	96.52	6609.31	59.87	2457.64	3320
Total					4953

* % recoverable savings are estimated at 80%.

Estimated savings

Furnace	**Savings in power KWh/year**	**Savings in Rupees/year**	**Investment required Rs.**	**Simple payback period**
A2	9,072	26,490	20,000	9 months
B3	20,265	59,173	20,000	5 months
Total	29,337	85,663	40,000	-

In addition to savings to the tune of Rs 0.85 lakh per annum, heat given to furnace body can be reduced due to low thermal mass of ceramic fibre. The down time production cost has not been considered as the replacement of refractory bricks with ceramic blankets was decided to be taken up only during annual maintenance of the furnace.

Energy Savings due to Increase in Furnace Volume

Replacing the existing refractory bricks with ceramic fibre blanket in the furnaces, in addition to bringing down surface losses, will increase the effective furnace volume. This is due to reduction in the insulation thickness from existing 30 mm to proposed 20 mm. Hence it increases the furnace effective loading volume thereby improves the furnace actual loading, which in turn decreases the no. of cycles per month. This measure can result in estimated annual savings of 99,916 kWh (i.e. Rs 2,91,175/-).

5.12 Efficient Ladle Preheating System

In a plant situated in Southern India Producing Different cast wheels and axles, there are two ladle preheating stations. Only one will be in operation at a time. The ladle is preheated up to 900 – 1000°C in horizontal ladle preheating station with the burners located centrally in the ladle. The preheated ladle is sent to electric arc furnace for tapping molten metal, and for casting. The fuel used is HSD. The average HSD consumption in 175 litres per hour and the furnace is operated for about 16 hours per day.

The high exit flue gas temperature and huge quantity of flue gases indicate potential for waste heat recovery by preheating the combustion air up to 400°C. The ladle waste recovery systems are available in both horizontal and vertical heating stations. The detailed economics is given below. The efficient ladle preheating system is given in Annexure 3. Feasibility was studied to recover the heat in exhaust gases after considering the excess air level of 20 – 30%. Summary of the techno-economics of the measure is tabulated below :

Recoverable heat, kcal/h	Savings in HSD, kl/y	Estimated cost savings, Rs.lakh/y
160373	89.60	5.93

The flue gases account for 35% of total heat input. Some portion of heat in the flue gas can be recovered by preheating the combustion air.

Type of fuel	:	HSD
Required flow rate of fuel kg/h	:	147 kg/h
Required air flow (based on 20% excess air)	:	2064 kg/h
No. of working hours per year	:	5000
No. of burners working	:	1
Flue gas temperature	:	860°C
Combustion air temperature	:	30°C

Analysis

Quantity of flue gas (kg/h)	:	147+2064
	:	2211 kg/h
Heat in flue gas	:	2211x0.25x(860-30)
	:	458783 kcal/h

Proposal :

Installing a recuperator for preheating combustion air :

Acceptable air temperature limit by burners	: 400°C
If the air is heated by the flue gases up to 400°C the heat can be recovered	: 2064x0.21 x (400-30)
	: 160373 kcal/h
Percentage possibility of heat recovery	: 35% of heat in flue gases
	: 10.36% of fuel input

Savings :

HSD savings	: 15.23 kg of HSD
	: 17.92 litres of HSD
	: 17.92 x 5000
	: 89.6 kl/year
Monetary savings	: Rs.5.93 lakh/year

Investment required :

No. of recuperators required	: 2
Cost of recuperator	: Rs.3.0 lakh
Total investment required	: Rs.6.00 lakh
Payback period	: 1 year

Section 6 - Checklist

6.1 Coal Fired Furnaces

Storage and Preparation

- Stack coal in neat heaps not exceeding 1.5 meters in height and limit the individual heaps to 200 metric tonnes.
- Stack coal on hard ground and ensure a tightly packed heap to subdue ventilation, which could lead to spontaneous combustion.
- Coal should be properly sized as per the requirement.
- The wetting of coal should be done carefully and the quantity adjusted according to the content of fines in the coal.
- Do not store coal in big heaps and on slushy surfaces.
- The wetting of coal is limited when the fines content reaches a limit of 40% further addition of water should be avoided in case it is more than 40%.

Coal Combustion

- Maintain coal size and wetting of coal to recommended limits as far as possible to avoid segregation and choking of the fire grate.
- The primary as well as secondary air may be regulated according to the coal bed thickness and volatiles contents of the coal being used.
- Periodic sampling of exit flue gases and corresponding adjustment of air supply are important in order to maintain optimum level of carbon-di-oxide percentage (12-14%).
- Keep the blower position off when ash is cleaned from fire grate.
- Stoke the fuel (in hand firing system) in small quantities and at more frequent intervals.
- Set the chimney damper in such a position that the combustion chamber works under slightly positive pressure.
- Clean the clinker formation on bridge and side walls as and when it occurs.
- Complete cleaning of fire grate and ash pit may be done during weekly off.
- In the case of a fixed grate natural draft system a castable grate is recommended instead of a 'lose' bars grate.
- Close the damper when the furnace is stopped.
- Do not permit segregation of coal particles on the fire grate.

- Do not operate with too thick a fuel bed.
- The supply of primary and secondary air should not be same at different fuel bed thickness.
- Do not operate the blower during ash cleaning.
- Do not fire coal in case there is a big clinker formation.
- Do not operate the furnace in a negative draft particularly in the case of a re-heating furnace.
- Do not disturb the fuel bed too much and too often by "hooking" and "poking".
- Avoid maximum opening of surface doors.

Waste Heat Recovery

- Preheat both the primary as well as secondary air for combustion.
- In case the exit flue gas temperature is more than 1000°C use a ceramic recuperator or regenerator for waste heat recovery system.
- Never allow more than 950°C flue gas temperature to reach a metallic recuperator. Use a dilution air blower if it is excessive.
- Bypass flue gases during cold start up till it achieves the desirable temperature.
- Check all joints to prevent air leaks.
- The insulation on a hot air pipe line should be thoroughly checked.
- Soot and flyash deposition both inside and outside the tubes should be cleaned regularly.
- Do not allow combustion air temperature to increase more than 150°C, in case of fixed grate firing system.
- Do not locate metallic recuperator (shell and tube type) near the furnace (important for high temperature furnaces).
- Do not locate dampers just before and after a recuperator.
- In the case of a regenerator do not set reversal time either too short or too long.
- Do not use cheap refractory in regenerator chequer brick (particularly in the upper layer).

Reducing Heat Losses

- Appropriate thermal insulation of furnace surfaces is required, if skin temperature is more than 60 – 70°C.
- Set the chimney damper in such a position, as to maintain furnace pressure slightly positive, to obviate ingress of cold air.
- Furnace doors and other openings should be kept closed as far as possible to prevent excessive radiation losses.
- The material should be kept inside the furnace and not allowed to project outside the furnace.
- Do not use thermal insulating material like glass wool or mineral wool if there are small leakage in the furnace structure.
- Do not use cold face insulating bricks without proper support.

6.2 Oil Fired Furnaces

- Ensure proper storage, handling, preparation of fuel for efficient combustion and good flame temperature.
- Ensure uniform heat release and constant atmosphere throughout the furnace width by controlling the air and flue gas distribution to the furnace chamber.
- Flame path should be controlled to prevent burning of the stock or impact on the furnace refractories leading to rapid failure.
- Maintain optimal excess air levels, so as to ensure complete combustion while keeping stack gas temperature at its minimum. This is essential to ensure efficient furnace operation.
- Ensure static pressure control related to the furnace geometry to restrain air infiltration or blowout of the flue gas. A reasonable pressure to aim for is about 2.5 Pa (0.01 in W.G.) and this should be measured at the hearth level to avoid the buoyancy effect.
- Location of the load in a furnace should be carefully done, as a badly located load can spoil the operation of a good furnace by affecting the recirculation of gases.
- Furnace should always be loaded to the maximum extent possible as the furnace performance is judged on the fuel consumed per unit of stock produced.

- Workout the economic thickness of insulating bricks based on computation of furnace surface heat losses. Ceramic fibre insulation with mineral backing is an attractive and relatively new form of construction for furnace chamber walls and roof.

- Investigate waste heat recovery option from exhaust gases to preheat combustion air.

- The location of waste gas off-take should in general be as far from the burners as possible, but their location is not critical with furnaces operating under slight positive pressure.

- When air (or fuel) is supplied to several burners by a manifold, it is important that this be large enough to act as plenum chamber, otherwise the flow to some burners will be excessive and the others may be starved, resulting in a badly heated furnace.

6.3 Electrical Resistance Furnaces

- Oven construction and design of heat circulating system should depend largely on the kind of products that will receive the heat. i.e. shape, mass density, stacking arrangements and materials.

- Use of thermocouples for each zone working with controlling instruments is vital for any electrically operated resistance furnace. If possible excess temperature monitoring thermocouple should be employed to disconnect the power supply in the event of mal-operation of the normal temperature control devices.

- Furnaces with fan assisted convection heat transfer, the energy consumed by recirculation fan motors should be optimised. When such fans are more in number or whenever furnace loading is subject to variations, it is justifiable to use variable frequency drive for energy savings.

- The furnace opening should be kept to minimum as far as possible. In many cases the feeding door of the continuous heating furnace has more opening than the height of the product that is fed in.

- The furnace should be loaded optimally by planning the material flow to and from the heat treatment departments. This assumes importance as the performance is basically judged on the energy consumed per unit of stock produced.

- The furnace should be effectively insulated with ceramic fibre backed mineral wool. In continuous long-term cycle furnaces the insulation is to prevent the escape of heat through the walls and roof. In intermittent or short-term cycle furnaces, it is to reduce the heat storage loss while not neglecting to reduce the external surface loss. Ceramic fibre is the ideal insulating material for intermittent batch furnaces.

- The mass of the supporting structures of any product should be as low as possible for the given mechanical strength.

6.4 Induction Furnaces

- Keep holding periods to minimum as the cooling water losses are very high with longer holding periods.

- Minimise the tap-to-tap time to reduce the radiation and convection losses and for effective capacity utilisation.

- Use pyrometers to measure the accurate temperature of melting to avoid the unnecessary superheating of the liquid metal.

- Minimise the opening of furnace lids, slagging door, etc.

- Explore the possibility of charge compacting and preheating.

- Monitor the cooling water inlet and outlet temperatures and flow rates to assess the condition of the furnace refractory lining and the coil losses.

- Determine the melting capacity of the furnace as precisely as possible for the given type of casting or for mild steel ingots. This is because too large a capacity than needed would mean very high heat losses.

- Match the furnace capacities and production rates judiciously for maximising the furnace load factor. (to reduce the cost of energy per unit of output).

- Maintain the performance index (kg/h at a specified temperature per kVA) on a regular basis for effective performance monitoring of the furnace.

6.5 Electric Arc Furnaces

Elimination of delays is one of the surest methods of saving energy. It is essential that the entire operation of the furnace, furnace preparation and repair, charging, melting, refining, finishing and tapping are all well planned.

Charging

- The initial charge should always be of maximum density to achieve the required heat tonnage with a minimum number of recharges after the initial meltdown starts.
- The selection of charge should be carefully done to suit the meltdown operations. In case of alloy steel production it should be to result in a meltdown bath analysis that is close to the product specifications. Carbon in the charge may be adjusted to yield suitable melt required for common steels, or carbon percentage may be adjusted considerably more for higher quality, in order to gain full benefits of the carbon boil.
- The non-conductive material should be excluded from the charge as completely as possible to avoid the unnecessary heating up.
- The addition of lime to be charged should be determined after the analysis of scrap quality and the desired product.
- The charge placement in the furnace should be planned to attain efficiency in charging and meltdown with particular emphasis upon the maximum degree of heat absorption.
- To start with, a small quantity of light stamping scrap is to be positioned to cushion the impact of the heavier pieces of scrap as they fall into the furnace. Heavy scrap should be placed in the centre of the charge and should be located within the electrode. The furnace charge should be completed by placing sufficient quantity of medium and low density scrap on top of the heavier pieces.

Melt Down

- The electrodes should be lowered as close as possible to the charge by push button operation to reduce the time required for the automatic control to lower the electrodes and strike the initial arc.
- Suitable voltage levels should be selected to inject enough energy into the arc to allow the electrodes to bore down into the charge until they approach the

heavy scrap at the furnace bottom. This practice permits the greatest absorption of the arc energy by the charge and promotes the economic use of electric power.

- Once the primary bath has been formed at the bottom of the furnace, the scrap is melted by heat transmitting through the steel bath as well. Melting continues at this power level until the bath temperature requires this power. In some cases, it may be necessary to cut off power during this late melting period to raise the electrodes and to push any scrap which may have clung to the side walls above the bath.

- If the scrap is not dense enough to get the required charge weight into the furnace in the initial charge the remaining of the scrap is charged as soon as the scrap is melted to the level mass.

Typical Delays that Affect Energy Input

- The melting procedure is seriously affected by delays in crane service or in scrap delivery, shutdowns for power demand and mechanical failures.

- Scrap charge of incorrect chemical analysis sometimes necessitates changing the furnace schedules and melting to different specifications. The analysis of above delays (due to incorrect chemical analysis of scrap) and energy losses due to rescheduling of furnace loading should be reviewed for optimising energy consumption (thus restoring normal furnace schedules).

- Pieces of scrap placed along the sidewalls of the furnace may fall against and break the electrodes during meltdown.

- Electrodes may be broken by contact with any large concentration of insulating material in the charge, such as lime stone, since the electrode drive will continue to exert downward force as long as current in that leg of the circuit is low.

- Errors in the selection of power input levels may result in slow melting rates and damage to the furnace roof lining.

Section 7 : Economic Analysis of Investments for Energy Conservation

When any conservation opportunities are to be implemented, most measures do not require investments. However, it is possible that an investment, marginal or substantial, is sometimes incurred for specific energy saving opportunities. And, transferring the implementation from paper to actual practice involves making a decision - to invest or not to invest.

Usually, decisions are made regarding alternative solutions for utilisation of capital. At the outset, the decisions must not conflict with the objectives of the enterprise. These objectives can be constrained by social considerations or governmental regulations. They can be influenced partially by the owner's tastes or time required for implementation. However, the prime objective does not deviate from profit maximisation.

In order to aid the decision-makers, there are certain economic methodologies, which are followed. These are briefly discussed, although progressing beyond basic concepts would be beyond the scope of this manual.

All these methods are more or less reliable, depending on the accuracy of evaluation of the cash inflow and outflow, estimation of the discount rate (cost of capital) and prediction of the possible rate of increase of the energy price. Within these limitations, the most precise method is the Present Value Criterion, which compares the present value of all future after-tax cash inflow and outflow over a specified period of time to the present value of the cost of investment for the investment.

Although it may appear elementary, one has to recall here the fundamental rule of sunk costs, which says that in taking decisions about future investments, no role is played by past costs.

For example, when a new line of products is considered in a factory, the original book value of the existing old machinery already installed as irrelevant from the point of view of future cost evaluation. What is relevant is the present book value of the equipment, in the case that the old machinery can be sold or partially used to substitute the purchase of the new machinery. If the old machinery cannot be sold or used in the new production it is a "sunk cost" and has no relevance to the investment decision concerning the new machinery.

7.1 Present Value Criterion

The net present value (NPV) is defined as the difference between present worth of savings and cost of investment. The investment should be made if NPV is positive, and should be discarded if NPV is negative.

The present value method converts the money time series corresponding to the savings to an equivalent single amount at the date (year 0) when the decision to invest is to be taken. The present value criterion then compares this equivalent amount to the capital to be invested.

$$NPV = p \times \frac{1}{(1+r)^n}$$

Where p = future payments and income

r = pre-determined discount rate

n = number of years for which NPV is calculated

NPV indicates the return that the management can expect from the project at various discount rates. It can also be used to compare various projects with similar discount rates and risks, as well as compare them against a benchmark rate.

Internal Rate of Return (IRR) is the threshold rate at which the NPV is zero. It is the rate of return received for the project considering payments and income at regular intervals. This is commonly used for analysing investments in projects. A project is considered viable, if its IRR is greater than the interest rate offered by financial institutions for investing the capital with them that would be otherwise invested in the project.

7.2 Average Rate of Return Criterion

The average rate of return on investment criterion is not so precise as the present value criterion but it can provide a preliminary guide to investment decisions provided that the projected future annual cash savings can be assumed to remain constant.

For example, suppose the installation of a heat recovery device is considered. The heat recovery system installation costs Rs.10,00,000 and will last five years. The law permits a 20% annual linear depreciation factor. The new machine is expected to save Rs.3,00,000 in fuel costs annually.

7.3 Return on Investment (ROI)

The returns may be on the investment made or on a particular project or of the organisation as a whole.

Return on Investment (ROI) : Profit/Capital Employed

ROI is a combination of two ratios i.e., Profitability Ratio and Capital Turnover Ratio

Profitability ratio indicates the profitability of the organisation/investment/project while Capital Turnover Ratio indicates the efficiency with which the assets / investment are being employed. Greater the two ratios, higher will be the return on investment.

Generally the management analyses Profitability Ratios to take decisions pertaining to pricing policies, costs etc., while the Capital Turnover Ratio is analysed to take investment decisions.

The expected Return on Investment is generally the benchmark for investment decisions.

7.4 Pay-Back Period Criterion

The Pay-back Period Criterion evaluates the time required to recover an initial investment via an annual net cash flow. It is defined as the investment cost divided by the cash flow. In the previous example of the heat recovery systems, the pay-back time in years is equal to 3.3 years.

Similar to the return on investment method, the pay-back criterion does not take into consideration the discount rate, the change in energy prices, nor the lifetime of the investment project. It has one advantage over ROI in that a precise indication of the annual benefit, namely the cash flow, is used instead of profits. However, both suffer from the difficult, in justifying the threshold value beyond which no project should be considered.

In practice, investment projects with a pay-back period of three years or less almost always have a positive net present value. Thus the pay-back period is often used as a "filter", calculating NPV when the payback period is over three years and accepting the project when it is less.

7.5 Break-Even Parameters of Net Present Value

An important part of investment analysis, not to be confused with the pay-back period, is the calculation of the threshold value of a critical parameter of the net present value (NPV).

The threshold, or break-even value, is the value of a NPV parameter for NPV equal to zero. Any value beyond the break-even value will cause NPV to become positive and the investment acceptable.

Typical parameters studied in this manner include:

- The price of the service;
- The utilisation of the capacity of the investment;
- Various items of the cost of the project;
- The energy price increase, and
- Occasionally, the duration of the project.

When the latter is used as a parameter, the break-even time (in years) is a "true" pay-back period, where the discounted benefits begin to exceed the discounted costs.

Section 8: Energy Audit Approach and Methodology

8.1 Preliminary Energy Audit (PEA)

PEA is a preliminary data gathering and analysis effort in two parts: (a) the energy management audit, wherein the auditor acquaints himself with investment decisions and criteria referencing energy conservation projects and (b) the technical energy audit using available data.

The energy auditor relies on his experience to gather all relevant written, oral or visual information that can lead to a quick analysis of the existing energy situation. It focuses on the identification of obvious sources of possible improvement in energy use, such as missing insulation, steam and compressed air leaks, inoperative instrumentation and superfluous operation. The typical output of a PEA is a set of recommendations for immediate low-cost actions and, usually, a recommendation for a detailed energy audit.

8.2 Detailed Energy Audit (DEA)

This is a measured survey followed by a plant energy analysis. Sophisticated instruments, such as flow meters, psychrometers, flue gas analysers and infrared scanners are used to enable the auditor to compute efficiency and balances during typical equipment operation. The tests performed and instruments required depend on the type of facility, the objective, scope and level of handling of the energy management programme. The tests conducted include combustion efficiency tests, measurement of temperature and airflow of major fuel-using equipment, determination of power factor degradation caused by various pieces of electrical equipment and testing of process systems for operation within specification.

After obtaining the results, the auditor validates them using preliminary computation and existing support materials such as tables and charts. Then, he builds energy and mass balances, first for each major piece of equipment tested, and then, for the plant as a whole. From such balances, he can determine the energy efficiency of each equipment and scope for possible improvement in efficiency, with costs and benefits of selected options for each opportunity. In some cases, he is unable to recommend a specific investment because of its magnitude or the associated risk. In such a case, he may recommend specific feasibility studies such as boiler replacement, furnace modification, steam system replacement and process changes. The detailed report presents the auditor's recommendations, with costs, benefits and implementation aspects.

8.3 Steps in Energy Audit Programme

In an Energy Audit, detailed data are collected and analysed. Although sophisticated instruments are used, energy auditing is not an exact science. The auditor must use his knowledge and judgement to collect and interpret data suitably. The various steps in an energy audit programme are given below:

Step 1. Review energy management programme to date

The programmes are customarily reviewed with senior corporate staff. The auditor can decide what changes may be needed in the scope of the proposed detailed energy audit. If there is no formal programme, the auditor will try to understand why.

Step 2. Conduct preliminary energy audit

The preliminary energy audit (PEA) should be conducted after the review. The PEA consists essentially of gathering and analysing data. It uses available data only, without the use of sophisticated instruments. The results of the PEA depend on the ability and experience of the auditor. The output of the PEA is normally:

- ➢ *Development of energy consumption / cost data base for a facility*
- ➢ *Objective evaluation of plant condition*
- ➢ *Identification of major energy-consuming systems*
- ➢ *Understanding of company policies for energy-related projects*
- ➢ *Action plan for future energy auditing work*

The PEA generally has six steps.

1. ***Organise resources***
    - *Manpower / time frame*
    - *Instrumentation*
2. ***Identify data requirements***
    - *Data forms*
3. ***Collect data***
   a. Conduct informal interviews
    - *Senior Management*
    - *Energy manager/co-ordinator*
    - *Plant engineer*
    - *Operations and production management and personnel*

- *Administrative personnel*
- *Financial manager*

Conduct plant walkthrough/visual inspection

- *Material / energy flow through plant*
- *Major functional departments*
- *Any installed instrumentation, including utility meters*
- *Energy report procedures*
- *Production and operational reporting procedures*
- *Conservation opportunities*

4. Analyse data

a. Develop database

- *Historical data for all energy suppliers*
- *Time frame basis*
- *Other related data*
- *Process flow sheets*
- *Energy - consuming equipment inventory*

b. Evaluate data

- *Energy use - consumption, cost, and schedules*
- *Energy consumption indices*
- *Plant operations*
- *Energy saving potential*
- *Plant energy management programme*

5. Develop action plan

- *Conservation opportunities for immediate implementation*
- *Projects for further study*
- *Resources for detailed energy audit*
  - *systems for test*
  - *instrumentation - portable and fixed*
  - *manpower requirements*
  - *time frame*
- *Refinement of corporate energy management programme*

6. Implementation

- *Implement identified low cost/no cost projects*
- *Perform Detailed Audit*

Step 3. Develop action plan, including detailed energy audit

On the basis of the review and the PEA, the energy auditor should develop an action plan, including a Detailed Energy Audit (DEA), considering:

- *Management of energy-related matters*
- *Monitoring and reporting considerations*
- *Relationships with manufacturers' representatives*
- *Availability of resources for implementing the action*

Step 4. Select scope of detailed energy audit

The next step is to determine the scope of DEA, in order to finalise resources requirement in the following areas:

- *Manpower: Manpower required for the DEA should be selected, on the basis of the review of the PEA, from internal or external sources.*
- *Instrumentation: The DEA provides the basis for the quantitative analysis of the energy performance of the facility. To compile the operating data necessary to make this quantitative assessment, a variety of fixed and portable instrumentation is used.*
- *Testing procedures: There are standard testing procedures for evaluating equipment performance, which the auditor may use as guidelines. For example, BIS 8753 provides methods for calculating the combustion efficiency.*
- *Cost for conducting the DEA: This depends on the time required to complete the DEA, in other words, the size of the plant and the report preparation time. The use of sophisticated instrumentation and overheads also add on to the cost of the DEA.*

Step 5. Complete preparatory work

All instruments should be calibrated, serviced and/or repaired, additional instruments purchased and test measuring positions and connections completed. The auditor should make sure that the time selected for the audit does not conflict with the operation of the equipment to be tested or the plant in general. The testing date should also be representative of normal plant operation.

Step 6. Carry out detailed energy audit field work

The energy auditor can now conduct the fieldwork for the DEA, which comprises two main tasks:

The first task is to gather data to evaluate all energy aspects using the PEA as a starting point, expanding on it, to fill gaps and learn more about the plant operation.

The auditor usually interviews selected personnel, examines records, observes operations, monitors and checks conditions. This may involve repeated data collection and review.

The most important part of an energy audit consists of the preparation of energy and material balances, first for individual equipment operations and then, for the entire plant. Without such data, it is rarely possible to carry out quantitative analyses to identify potential energy savings. Instruments play a vital role in measuring, indicating and controlling process parameters to achieve energy efficiency.

The second task is to perform tests on selected equipment to evaluate its efficiency.

Step 7. Evaluate collected data

Based on the raw data generated, efficiency of various equipment is evaluated. This involves detailed calculation, using computers and at times, specially designed software.

Step 8. Identify conservation opportunities

The results of the evaluation can be used to identify the energy conservation opportunities:

- *Better operation and maintenance by low-cost housekeeping measures*
- *Recovery of waste energy*
- *Improvement in equipment efficiency*
- *Installation of advanced control systems*
- *Change of technology*

These low cost opportunities require little or no major capital investment and have immediate returns on investment. On a simple payback basis, they have paybacks of less than a year.

Capital-intensive measures require large investments. Simple payback periods are usually more than a year. The auditor should use payback period as a guideline, while making his list of recommendations. He should also keep in focus, the attitude of the management towards capital-intensive projects.

Step 9. Develop action plan of implementation

The auditor will probably not have the authority to implement the measures identified, especially if capital requirements are large. Instead, he will complete a report, which will present his findings, with a concrete and time-bound action plan.

It should usually be possible to implement some O&M measures immediately. However, capital intensive measures may require feasibility studies before a decision can be made to implement them.

An action plan often includes a recommendation for self-financing. In a self-financing programme, O&M changes are implemented and the resulting cost benefits are invested directly in lower-cost capital-intensive measures to bring in more savings. Eventually, these savings are used to pay for the most capital-intensive measures.

Step 10. Continue to monitor energy use

Energy efficiency in a company cannot begin and end with the DEA. To sustain its energy efficiency, a company must continue to monitor its energy use.

The DEA report should recommend improvements to the existing monitoring and reporting procedures for energy use. Very few companies, if any, have an adequate system of monitoring procedures. Without such a system, it is hard to spot changes in consumption that result from increase or decrease in efficiency. Possible improvements that can be made to monitoring and reporting procedures include:

- *Upgrading of instrumentation*
- *Development of energy consumption indices*
- *Development of energy models*

Step 11. Refine overall energy management programme

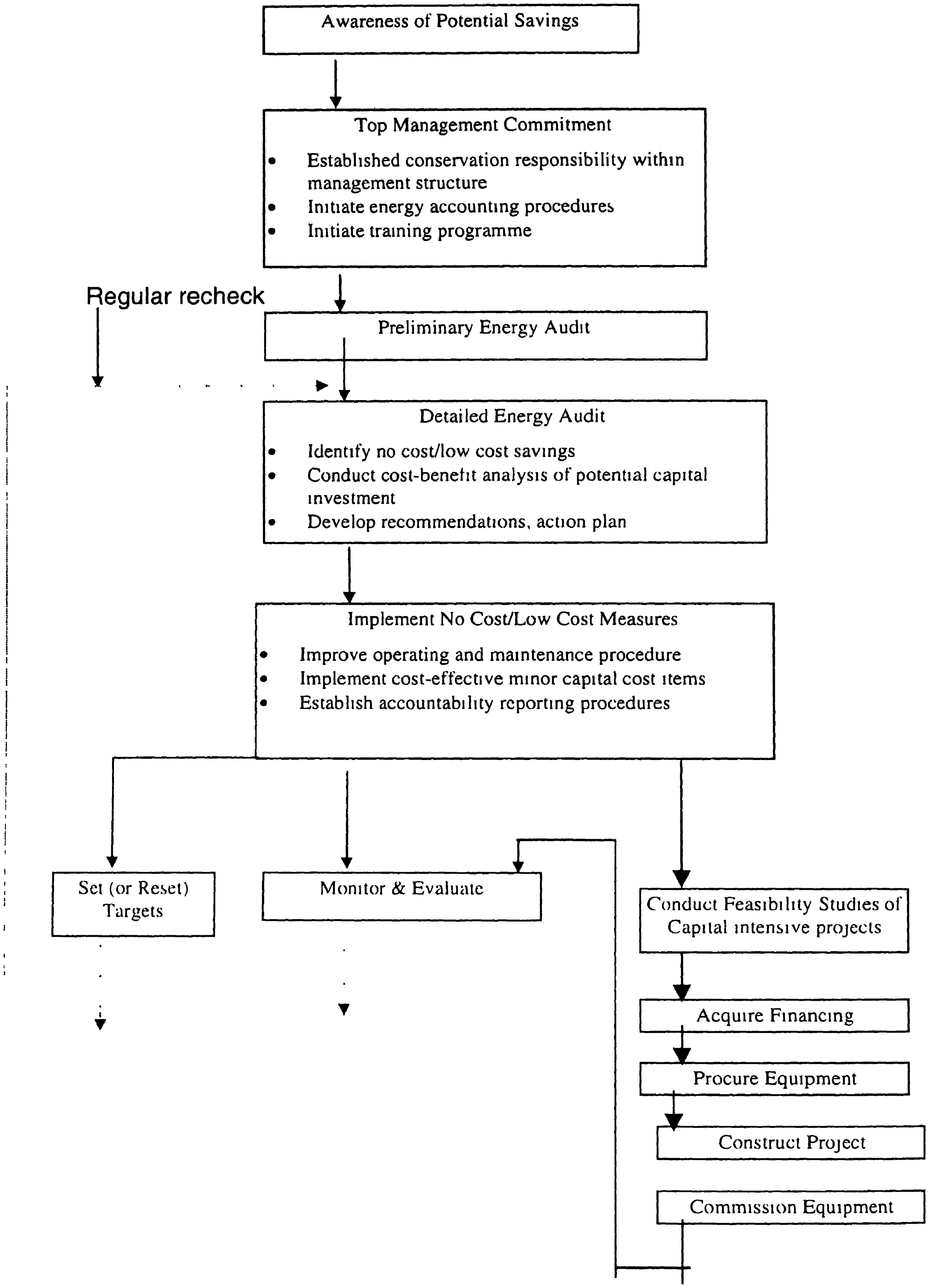
The major recommendations of the DEA should be refinements to the overall corporate energy management programme. Since energy affects so many aspects of operations, improvements in energy use cannot take place without commitment at the highest levels of management and a proper organisational framework. The management's perception of the state of energy use will determine the success of any energy management programme. Recommendations may include:

- *Appointing personnel to be responsible for energy*
- *Formally structuring a corporate energy management programme*
- *Training staff and employees in energy awareness*

In its efforts to maintain energy consumption within levels consistent with technological developments, the management may carry out regular energy audits to review the results of the improvement measures.

8.4 Energy Management Practice

The energy management process in totality can be represented as below:


Awareness of Potential Savings
Top Management Commitment
• Established conservation responsibility within management structure
• Initiate energy accounting procedures
• Initiate training programme
Regular recheck
Preliminary Energy Audit
Detailed Energy Audit
• Identify no cost/low cost savings
• Conduct cost-benefit analysis of potential capital investment
• Develop recommendations, action plan
Implement No Cost/Low Cost Measures
• Improve operating and maintenance procedure
• Implement cost-effective minor capital cost items
• Establish accountability reporting procedures
Set (or Reset) Targets
Monitor & Evaluate
Conduct Feasibility Studies of Capital intensive projects
Acquire Financing
Procure Equipment
Construct Project
Commission Equipment

8.5 The Approach to Energy Management

The commitment of top management should be clearly demonstrated in policies and directives, with company decisions to control costs being clearly defined. Active participation in energy related activities by senior management is a vital step in this approach. Chart A presents this concept schematically. Practising energy management includes mandatory functions such as:

- *Identification of possibilities for further improvement*
- *Evaluation of these opportunities to prioritise them*
- *Implementation of conservation measures*
- *Continuous monitoring to sustain and further improve upon these measures*

8.6 Preliminary Analysis

In order to develop an energy management programme, it is necessary that the scope, extent of detail and the management cost and time expended should have some relation to the potential benefits of the programme. The cost incurred should not be more than the value of energy saved. The preliminary analysis should include with a preliminary analysis of parameters such as:

- *Consumption of various forms of energy*
- *Energy cost as percentage of production cost*
- *Major energy intensive equipment*
- *Potential savings and comparison with current profit*
- *Cost of additional metering possibly required to introduce the programme*
- *Efforts within existing framework to monitor energy consumption in different departments.*

Such a broad evaluation would give a perspective of the management time and cost value in relation to potential returns.

8.7 Energy Committee

Within the company, and particularly for larger industries, an Energy Committee would play a vital role of co-ordination between various departments. This may, for example, include senior managers, the Accountant and the Chief Engineer. Since accountability and authority go hand in hand, the Chairman should be a senior functionary, with authority to ensure that all resources are made available for necessary actions.

The Committee will be responsible for:

- *Developing the energy policy*
- *Managing the monitoring system*
- *Concurring upon and reviewing standards and targets*
- *Examining energy saving schemes*
- *Ensuring project implementation*
- *Any other matters relating to energy*

8.8 Energy Manager

A full-time energy manager may be appointed to implement the energy management programme, directly accountable to the energy committee. This would also be evidence of the management concern for and commitment to energy conservation. The energy manager should be an internal appointee, to ensure good practical knowledge of all aspects of operations, both technical and administrative.

Responsibility for Results

In general, organisation structures in the industry are based on three levels of authority with corresponding responsibilities towards efficiency of energy use.

Level 1: *Senior Management with responsibility for energy efficiency in the entire organisation, in relation to other resources, and in production of particular products.*

Level 2: *Middle Management with similar responsibilities, but limited to specific areas of the manufacturing process or divisions of the organisation.*

Level 3: *Process Operators, Foremen and Supervisors with responsibility for maintaining efficiency in a particular item of plant or part of a process.*

At all levels, regular reports on actual usage compared against norms and targets will be equired in order to learn and correct deviations. The energy manager would provide these reports, analyse data, develop standards of performance and derive information for setting appropriate targets. He would also be responsible for installation and operation of metering systems and the training of staff for the collection and analysis of data.

8.9 Energy Management Process/Strategy

There are four distinct steps to the energy management process:

- *Defining energy accounting centres*

- *Measurement*
- *Analysis & Monitoring*
- *Targeting*

Energy Accounting Centres (EAC)

Along the energy flow paths of the plant, a series of energy accounting centres can provide the breakdown of energy input and output, for monitoring and achieving set targets. An EAC might comprise an individual equipment, a section or even a whole building. Each centre must have an individual responsible for both operational achievement and energy conservation, in order that his attention is focussed on the close relationship between the two aspects. He should have available pertinent information, on which to base judgements, decisions and actions to bring about improvements. Each EAC requires meters to measure the energy consumed over a period, and a means of measuring the production (or other specific variable) over the same period. As far as possible, EACs should correspond with the existing cost control centres.

Measurement

In order to be managed effectively, any resource must be measured accurately, to provide information to base decisions. Energy management depends on collection of relevant data, to judge current performance and plan for future improvements.

Analysis & Monitoring

Energy consumption and cost data can be collected and effectively used to analyse and evaluate performance. This involves regularly comparison of actual levels of consumption with a theoretical consumption defined by a set of internally based standards. These standards could be derived from a knowledge of the organisation's own capability, and then possibly further checked by reference to external norms. Difference between actual consumption and the corresponding standards will reveal either improvements in energy efficiency or a fall-off in performance levels. The information gathered, thus provides quantified evidence of the success of implementation, or will indicate any failures, in order that remedial measures can be undertaken.

The analysis should be a continuous process, and each line manager or plant operator must receive the energy throughput data regularly - on a weekly/ monthly basis - and promptly, so that deviations from standards can be quickly detected and corrected. In turn, line managers themselves must ensure that they respond rapidly to the information they receive. Well-designed reporting forms, expressed in readily understood terms, will be very helpful. Management information systems must ensure that the appropriate data and deviations reach the highest levels of authority. Just by the introduction of a monitoring system alone, many organisations have found that they could cut their energy consumption by up to ten percent.

Targeting

Once the energy management programme has identified and prioritised on the implementation of various measures, targets can be set for the implementation of change and the achievement of the predicted energy cost savings. The choice of targets will take account of current standards and the time frame for implementing measures. A organisation may wish to set a range of targets, taking note of the scope for improvement, the resources allowed by management to effect the improvement and the need to match accountability to the energy-accountable centres.

There are two principal methods of target setting. This first is the `top down' approach, a broad based generalised technique, which does not draw on a detailed analysis of the circumstances of the organisation, but may be based on experience in the sector as a whole.

The second `bottom up' method is based on a close knowledge of the energy requirements of different parts of an organisation. Both have their merits and can be chosen, depending on the efficacy in the given circumstances. Most organisations prefer the `bottom up' approach since it is, by its very nature, more closely tailored to there needs and hence more effective.

Correctly set targets have a strong motivational effect on the workforce. But it is important to avoid either impossible or too easy targets, since these can provide counter productive.

8.10 Importance of Human Element

Means of Getting Good Co-operation from Personnel

a. Education

A well-designed familiarisation programme should convince employees of the need for good standards of housekeeping and energy awareness. They should appreciate that it is in their best interests to avoid unnecessary and excessive use of energy. Energy savings add directly to profit. However, it is important to emphasise that sacrifices are not being sought, nor are the employees expected to work in less than satisfactory conditions. Early results are unlikely to be sustained indefinitely. People do tend to slip back into former habits, but the right climate can be established for introducing more complex and lasting measures gradually.

b. Awareness and information sharing

In most plants, employees have little or no idea of the amount of energy consumed within their plant, their section and even the equipment operated by them. In such a situation, what is required is awareness - which can be possible only by information, in the form of comparisons of historical trends, goals for overall energy use, energy intensity, in physical and monetary terms; checklists for each manufacturing operation outlining routine housekeeping measures, audio-visual presentations and literature.

Information must be presented in a manner that facilitates comprehension. If the information is too technical, theoretical, sketchy or dull, it is likely to be ignored or not understood. Terminology should be familiar to the daily life of the employees. For example, a sign saying, " stop steam leaks" will not be as effective as a sign saying " A quarter inch diameter steam leak costs Rs. 30,000/- per month".

Training is also an important means of both informing and involving people at all levels in an energy management programme. For operating personnel, training is required in practicalities of energy saving. This could be integrated into the organisation's other training programmes.

c. Motivation

Motivation is based on involvement, commitment and a sense of personal accountability. Top management must visibly demonstrate their attitude, originate the programme, generate and maintain the momentum.

Operators and maintenance staff should be involved actively, as they are ultimately responsible for execution. They are often in a better position to recommend areas for improvement. The most effective way of involving them is by simply going out and talking to them regarding goals, achievements, problems and progress or lack of progress.

Supervisors and middle level management should be involved by being assigned responsibilities for implementing and monitoring activities and submitting performance reports to top management, and by getting them to interact and communicate with operators and maintenance stand on progress and problems.

If possible, energy management activities should be made a part of each supervisor's performance or job standard.

d. Publicity

Publicity and promotion are essential to publicise the benefits to the company and the workforce. Some commonly used means could be:

1. Articles or implemented ideas in company or plant paper.
2. Obtain local newspaper interest and coverage.
3. Posters and pamphlets
4. Letterheads with energy conservation messages and ideas
5. Plant-wide, high-visibility vehicles or equipment to carry signboards
6. Monthly posting of results for the plant and department
7. Direct interactions of plant energy manager and personnel.
8. Quarterly site reviews and walk-through of unit.
9. An agenda item on energy conservation included at staff meetings.
10. Material provided to first-line supervisors for employee discussion periods.
11. Quarterly meetings held in the plant for all unit representatives
12. An Energy Awareness Day is set aside in the plant twice a year
13. Company energy logo developed and adopted.

8.11 Key Tasks of Energy Management

Energy Data Collection and Analysis

- *Maintain records of all energy consumption in the plant*
- *Check the reading of all meters and sub-meters on a regular basis.*
- *Specify additional meters required to provide additional monitoring capability.*
- *Develop indices for specific energy consumption relative to production and maintain these indices on a monthly basis for all major production areas.*
- *Set performance standards for efficient operation of machinery and facilities.*

Energy Purchasing Supervision

- *Review utility and fuel bills; ensure proper and optimum tariff application*
- *Investigate and recommend fuel-switching opportunities*
- *Develop contingency plans in the event of supply interruptions or shortages.*
- *Work with individual departments to prepare annual energy cost budgets.*

Energy Conservation Project Evaluation

- *Develop ideas, working with in-house staff, vendors and consultants*
- *Analyse economics to permit management evaluation of projects.*
- *Obtain management commitment of funds to implement projects.*
- *Re-evaluate projects in tune with growth of company*

Energy Project Implementation

- *Initiate equipment maintenance programmes for energy saving*
- *Supervise the implementation of conservation projects, including specification, requests for quotation, evaluation of offers, ordering of materials, construction/installation, training, start-up and final acceptance.*

Communications and Public Relations

- *Prepare reports to management, summarising costs and consumption*
- *Effectively communicate with all production and support departments*
- *Develop an awareness programme to encourage active participation*
- *Develop training programmes to upgrade knowledge and skills*
- *Publicise company commitment to energy conservation*

Checklist for Top Management

a. Inform line supervisors of:

- *Economic reasons to conserve energy.*
- *Responsibility for implementing actions in areas of accountability.*

b. Establish an energy committee consisting of:

- *Representatives from each department in the plant*
- *A co-ordinator appointed by and reporting to management.*

c. Provide committee with guidelines as to what is expected

- *Develop uniform record keeping, reporting and energy accounting.*
- *Research and develop ideas on ways to save energy.*
- *Communicate these ideas and suggestions.*
- *Suggest tough, but achievable, goals for energy saving.*
- *Develop ideas for enlisting employee support and participation.*

d. Set goals in energy saving, revising it based on savings potential

e. Employ external assistance in making recommendations.

f. Emphasise management's focus on conservation activities.

Duties and Responsibilities of Energy Manager/Co-Ordinator

- *Generate interest in conservation and sustain it with new ideas and activities.*
- *Summarise purchases, stocks and consumption, review and report utilisation.*
- *Focus of departmental records of use, ensuring uniformity and consistency.*
- *Co-ordinate efforts of energy users and set challenging but realistic targets*
- *Advise on techniques and source guidance on specialised subjects.*
- *Identify areas that require detailed study and prioritise them.*
- *Maintain records of all in-depth studies and to review progress.*
- *Provide basic handbook of good energy practice for operations.*
- *Advise purchasing, planning, production and other functions*
- *Ensure that health and safety are not adversely affected.*
- *Liase within industry to exchange ideas, protecting confidential data*
- *Contact research organisations, manufacturers and professional bodies*
- *Remain up-to-date on national energy matters and advise senior management.*

8.12 Instrumentation for an Energy Audit

Thermal related measurements:

The most common parameter measured is temperature. All evaluations of the heat contents of a stream or the energy consumption of a process depend on the temperature at each point of the stream or in the process. The instruments commonly used for measuring temperature are:

- *Mercury/ Bimetallic thermometer*
- *Thermocouple and indicator*
- *Thermograph*
- *Data logger*
- *Pyrometer*
- *Hygrometer*

Mechanical related measurements:

Flow measuring instruments:

- *Vane anemometer*
- *Pitot tube*
- *Air flow meter*
- *Orifice meter*
- *Venturi meter*
- *Ultrasonic flow meter*

Pressure measuring instruments:
Ultrasonic Leak Detectors
Speed measuring instruments:

- *Tachometers (Contact and Non-Contact Type)*
- *Stroboscope*

Steam trap-testing instruments:

- *Industrial stethoscope*
- *Electronic trap tester*

Chemical related measurements

- *Fyrite kit (percentage CO_2/ O_2 in the flue gas)*
- *Oxyliser (% O_2, CO_2, flue gas temperature and combustion efficiency)*
- *Flue gas analyser (%O_2,CO_2,flue gas temperature and combustion efficiency)*
- *Dragger (CO)*

Electrical related measurements:

- *Ammeter and Voltmeter*
- *Power factor meter*
- *Power analyser (A,V, pf, kW, kVA, Hz)*
- *Current recorder*
- *Multi-meter*

Lighting related measurements:

- *Lux meter*

Annexures

Iron and steel castings differ from each other in chemical composition, metallurgical characteristics and other properties, such as compressive strength, tensile strength, malleability and ductility. Iron castings have high compressive strength, low tensile strength and low malleability. These castings are mainly used in applications involving compressive loads, such as machine beds and frames. Inferior iron castings can be manufactured at low costs, for use in a variety of applications such as sanitary pipes, cisterns and other sanitary castings and slag pots.

Here, the percentage of carbon varies from 2 to 4%, silicon 0.85 to 4%, manganese 0.2 to 0.8%, phosphorous less than 0.2% and sulphur less than 0.1%. In grey iron castings, carbon is present in free state in the form of graphite flakes or needles. By suitably adjusting the chemical composition and microstructure, it is possible to impart toughness and malleability to iron castings to a certain degree. These are called malleable iron castings and have lower carbon and silicon,. with the carbon dispersed in small specks throughout the structure as compared to free flakes or needles as in the case of grey iron. Malleable iron castings find application mainly in automobile components apart from various agricultural implements, pipe fittings and brackets.

Spheroidal graphite (SG) iron castings are another variant of iron castings, where the carbon is almost entirely in the form of graphite nodules in its microstructure. This characteristic imparts more strength, toughness and resistance to the casting than malleable iron. These castings find wide application in components of automobile/tractors, railway equipment and substitute more costly steel castings in certain applications.

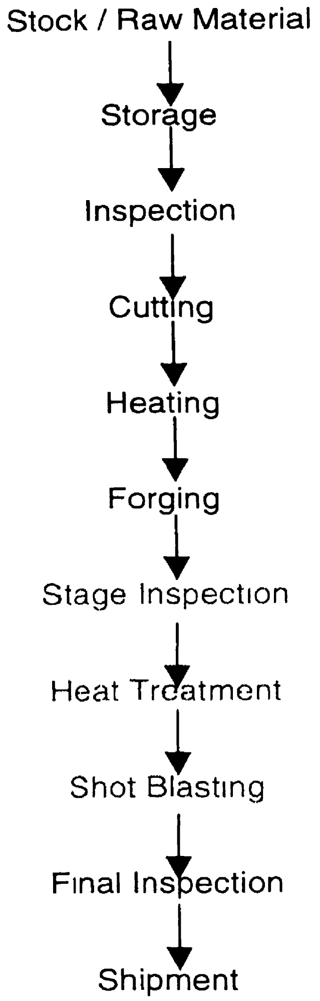
Steel castings are used in applications involving high tensile strength, toughness, malleability and ductility, where iron castings would normally crack or break under the tensile loads. Typical examples include bogies frames, high tensile couplers, manganese steel points and crossings for railways; body castings for refinery valves, petro-chemicals, fertilisers, thermal plants, steel, paper and sugar mills; rollers for coal units, cement and thermal plants; kiln drives, girth gears, rolling mill stands, gear blanks.

The essential difference between cast iron and cast steel is in the amount of carbon present in the metal - 0.1-0.8% in cast steel as against 2-4% in cast iron and in the metallographic structure. In steel castings, carbon is not present in free state, but it forms a solid solution in iron. Steel castings are also amenable to heat treatment, which widens their area of application. A number of alloying elements such as nickel, chromium, molybdenum, manganese, silicon, boron, tungsten are added to produce a variety of wear, heat, corrosion and creep resistant steel castings. The weight of steel castings range from few grams to 100 tonnes per piece.

The salient features of the forging process have been examined under two broad groups:

Open-Die Forging (ODF) refers to the process of shaping metal by hammering or pressing between flat or simple contoured dies, while manipulating the work piece. In actual practice, large number of individual open-die forging techniques, such as blocking (cogging), slabbing, direct forging, upsetting, punching, enlarging and closing in are combined selectively to produce wide range of products.

The stock is heated in the heating furnace to a temperature of up to 1250°C before putting it into the forging press / hammer. After forging, the components are heat treated for relieving stresses, re-crystallisation of the metal and improving the metal structure. Typical process sequence in production of open-die forging is shown below.



The raw material for ODF is normally an ingot of appropriate grade of steel, the size related to the final product dimensions. The steel ingot can be made from the BOF (or LD-process) or the Electric Arc Furnace steel making, subject to refining and further treatments depending on the grade, product size and quality needed for the finished forging. The ingot sizes used may range from 1 to 450 tonne of appropriate cross section.

Equipment for ODF

Forging Equipment

Free or open forging is done in forging hammers or hydraulic presses. These are shown in Table 1.

Type of Hammer	Ram Weight	Application
Pneumatic and spring hammers	Up to 2 tonne	Light forging (up to 40 kg)
Air / steam hammers	1 to 3 tonne	Medium size forging up to 300 kg
Air / steam hammers	5 to 10 tonne	Shaped forging weighing up to 700 kg and plain shafts up to 1500 kg

For still heavier forging, presses are used. For example, hydraulic presses (800 to 10,000 tonne pressure) are used to produce heavy forging up to 240 tonne piece weight such as for machine building industry. Output rates increase by 30 to 50%, compared to air / steam forging hammers.

Furnace Equipment

Furnaces are required for heating ingots or re-heating forged pieces. They are usually oil or gas fired, and hearth or car bottom type. The latter have a definite advantage that they can be withdrawn into the forging shop to facilitate access to hot steel.

Accurate control of temperature within the furnace is essential. Thermocouples placed through the refractory lining at various levels inside of the furnace, with digital displays and continuous print on strip-chart recorders facilitate control.

Other Auxiliary Equipment

These include overhead cranes, manipulator or porter bars, press cranes, with rotators or idler chains. These are required for various supporting operations such as charging or removing of ingots from the furnace, transfer of material to and from forging press and manipulating forging during operation.

Close-Die Forging (CDF) involves progressive deformation of material between two halves of dies with cavities, which on closure, conform to the exact shape of the component. Preliminary shaping of raw stock before obtaining the final shape of the forging is accomplished in the roughing impression (in multi-impression dies). In some cases, when all impressions cannot be accommodated in one die block, the forging process is divided between two or more hammers. The close-die method is generally used for forging from a few grams up to 400 kg.

A typical flow chart for a close-die forging is shown below. The process starts with the cutting of raw material (steel), from round / square bars of 3 to 5 metres. Cutting of blanks to the required size is done by shearing, hacksaw, circular saw, abrasive cutting and gas cutting.

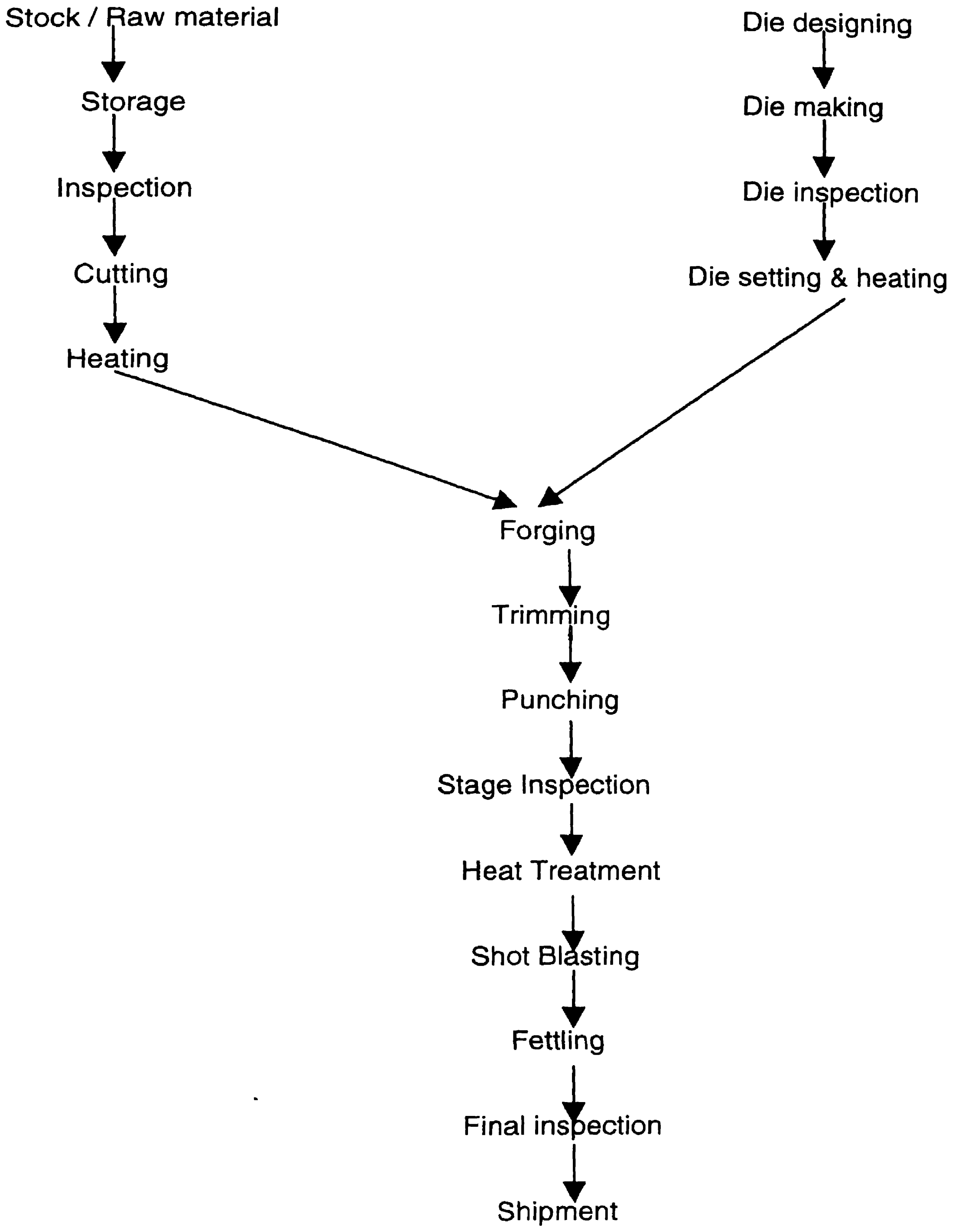
The bars or bar ends are heated in conventional oil or gas fired furnaces or by electrical heating (resistance / induction). After forging, the hot material is transferred from hammer or press to a trimmer press for removal of flash and then either allowed to cool or pass through a heat treatment process prior to finishing treatment, such as shot blasting and inspection.

Equipment for Close-die Forging

Forging Machine Equipment

Drop hammers are extensively used for production of close-die forging. These are relatively simple and cheap, but robust and reliable. The ultimate energy required for metal deformation can be accumulated by repeated blows. Earlier, steam pressure was used to drive the hammers, but the trend is veering towards air or hydraulic press, friction press and special presses. Presses are used only by few units and are suitable for large production runs, whereas hammers are cost-effective for smaller production runs.

Annexure 2 : The Forging Process



Auxiliary Equipment

Close-die forging is mostly achieved from cut pieces or off the bar. Shearing, hacksaw, circular saw, abrasive cutting and gas cutting machines are employed as appropriate, conventional oil fired furnaces are used for heating the cut pieces by most units and by electricity in some units. Other equipment in the forging plant are, trimmer press (for removal of flash), heat treatment furnace, shot blasting and other finishing equipment. Various instruments are needed to monitor the furnace operation. These are temperature recorders, pressure gauges, flow meters and gas analysers.

Concept

Electric arc furnaces are major energy guzzlers in the Secondary Iron & Steel Industry. The furnaces are used for melting of scrap and the recent trend is for melting sponge iron. The specific energy consumption for electric arc furnaces in India is around 650-700 kWh/t of metal melted. This is because these furnaces have not adopted the recent technological upgradations like ultra-high power, eccentric bottom tapping and hot heel practice, oxy-fuel burners, computerised melt controls, foamy slag practice, waste heat recovery etc. Technologies and practices such as these have enabled the world's leading companies to operate their furnaces at a specific consumption of 380-400 kWh/t.

Oxy-fuel burner is one such innovative technology, which has been prevalent in the Iron & Steel Industry. The idea behind this measure is to provide directional input of heat during the meltdown of scrap in the electric arc furnace. The heat is input by supplementing electric power with liquid/gas fuels.

The thermal distribution of heat in any a.c electric arc furnace is non-uniform. This is illustrated in Fig. 1. In an arc furnace, each arc delivers its heat to a section of the furnace in the vicinity of the arc. The three arcs repel each other by electro-magnetic force, thus creating a concentration of arc heat outside each electrode.

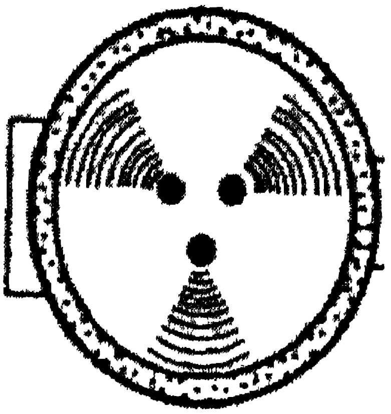


Fig. 1 : Heat Distribution in an Arc Furnace

This phenomenon leads to the formation of cold spots in the furnace. The meltdown becomes asymmetrical leading to slowing down of melting process and undesirable occurrences like metal splashing.

Burners are used to provide heat to the local cold spots, usually near the periphery of the bath or near the doors. These burners use liquid fuels or natural gas and oxygen is also delivered through the burner for combustion. Air is not used to prevent ingress of nitrogen and avoid unnecessary exhaust gas losses. Figures 2 & 3 illustrate the use of oxy-fuel burners on the sidewalls of a furnace.

The oxy-fuel burners can be introduced through the slag door or can be fixed to the sidewall or roof margins depending on the size and shape of the furnace and location of cold spots.

Fig 2 : External View of Oxy-Fuel Burner installed on Sidewall

The burners provide directional, controlled heat to the cold spots. The melting and heating process in the arc furnace is speeded up and the fixed losses by way of cooling water and surface are reduced. The electric power requirement is thus reduced and replaced on a smaller scale by heat from fuels.

Application Potential

Energy conservation by oxy-fuel burners is applicable to all electric arc furnaces in the secondary Iron & Steel Industry. There are nearly 200 electric arc furnaces in the country and around 40 furnaces are of 20 t and above capacity. It is more beneficial in furnaces where there is single or multiple charging of scrap. A larger size furnace would require 3 fixed oxy-fuel sidewall burners whereas a furnace of 10-15t may make use of an oxy-fuel burner introduced through the slag or side door.

Energy savings of 5-6% of the specific power consumption in electric arc furnaces are being realised by oxy-fuel burners. This technology is not used in any of the furnace units in the country. Thus a good potential for improved energy efficiency through this measure exists in the country.

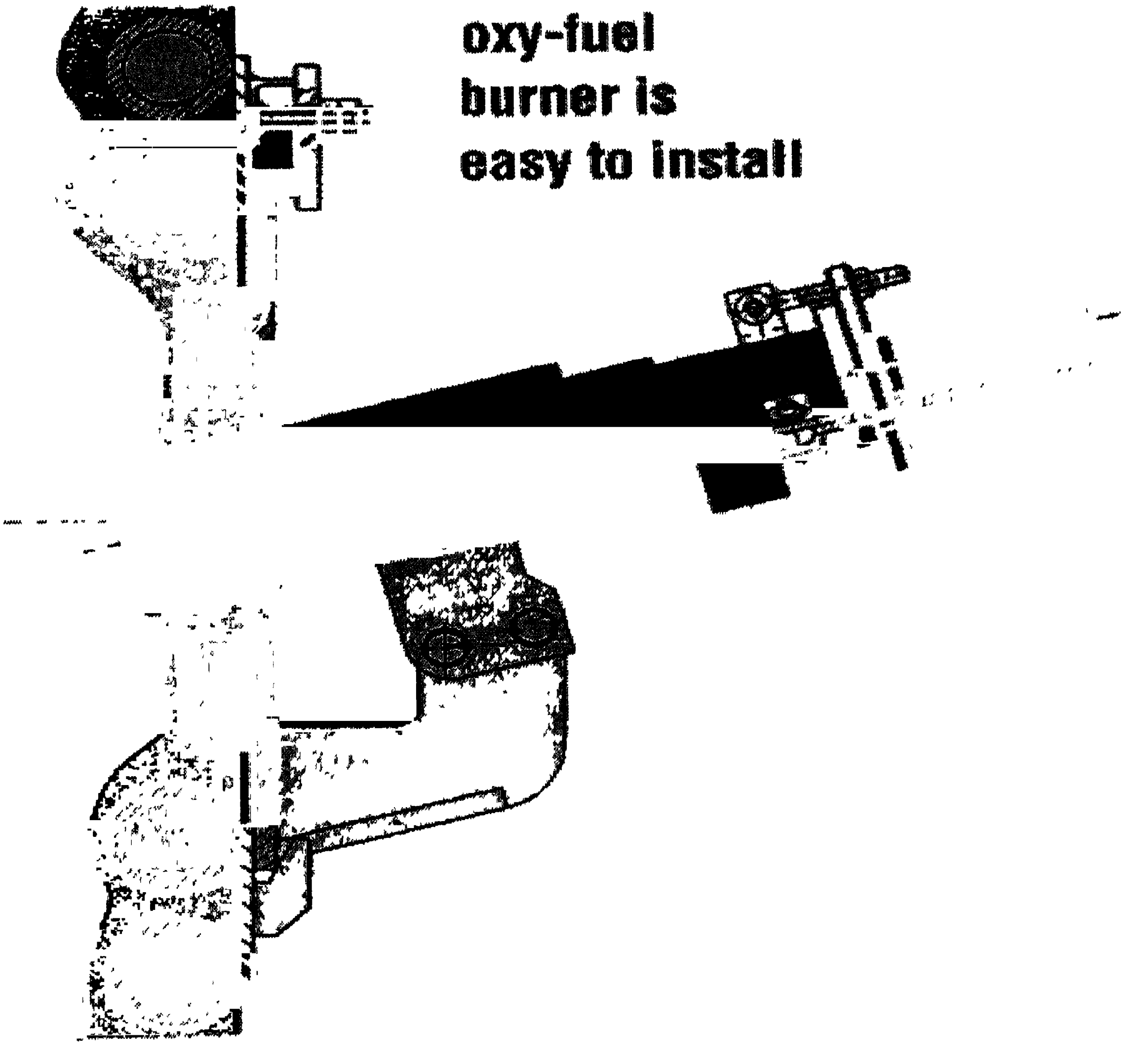


Fig.3 : Diagrammatic Representation of Oxy-Fuel Burner Mounting

Energy Saving Potential

The use of oxy-fuel burners has brought down the specific power consumption by a maximum of 40 kWh/t in electric arc furnaces. In addition to the energy savings, the other benefits are increased productivity and reduction in melting time. There is also a marginal decrease in specific electrode and refractory consumption.

The estimated investment could be Rs. 10-25 lakh, depending on the number of burners, type of fuel, local conditions in a unit etc. The payback period for oxy-fuel burners is 8-12 months even after considering operating cost of fuel and oxygen.

Existing Installations

At present, there are no Indian industries using these burners in the electric arc furnaces. It is reported that the burners have been tried at one or two arc furnaces and the experiment was not successful due to insufficient technological backup.

The arc furnace industry outside India has a large number of installations of oxy-fuel burners and it can be safely stated that it is a very common retrofit.

Annexure 4 : Efficient Ladle Pre-heating System

In any metal melting process it is very essential to maintain the molten metal temperature during pouring, transportation & casting. Ladles are employed to transport the liquid metal to casting facility. To avoid the drop in liquid metal temperature during transport and casting, pre heating of ladles are essential for efficient and safe operation. The other objectives of ladle preheating include avoiding thermal shock due to high temperature difference between ladle refractory & hot molten metal, driving off moisture present in the lining, preventing undue chilling of liquid metal & avoiding skull formation, to prevent solidification of molten metal in the ladle, etc.

The primary importance of ladle preheating cycle is to supply gradually a quantity of heat to the ladle walls and distribute it uniformly through out the refractory to obtain an adequate temperature gradient to over come the heat losses during transportation and pouring.

An oil-fired burner is commonly used for ladle preheating, where oil is fired in an open atmosphere. The heating station will be either vertical or horizontal. In case of steel melting units ladle refractory lining is normally preheated to the temperature between 700-1000°C and the oil consumption vary in the range 3.5-4.5 liters per Mt.

Though ladle preheating consumes substantial energy, it is often given a lower priority. None of the heating stations use heat recovery techniques and little attention is given to fuel economy.

The study of conventional ladle preheating study reveals the following:

- The efficiency of process given by the heat stored in the refractory varies in the range 25-45%. The energy efficiency of heating a cold ladle is as low as 10%.
- Major losses are flue gas losses, which accounts majority of heat input due to non-existence of waste heat recovery units.

Thus need for energy efficient ladle preheating arises with the following objectives:

- To reduce the energy consumed in preheating
- To reduce the energy consumed in melting units by avoiding the excess superheat of the molten metal
- To increase the lining life of the ladle
- To improve the working conditions in the shop
- To achieve more uniform heating.

Annexure 4 : Efficient Ladle Pre-heating System

A substantial improvement in energy utilization can be made in ladle preheating by simple changes and in-corporation of the waste heat recovery unit.

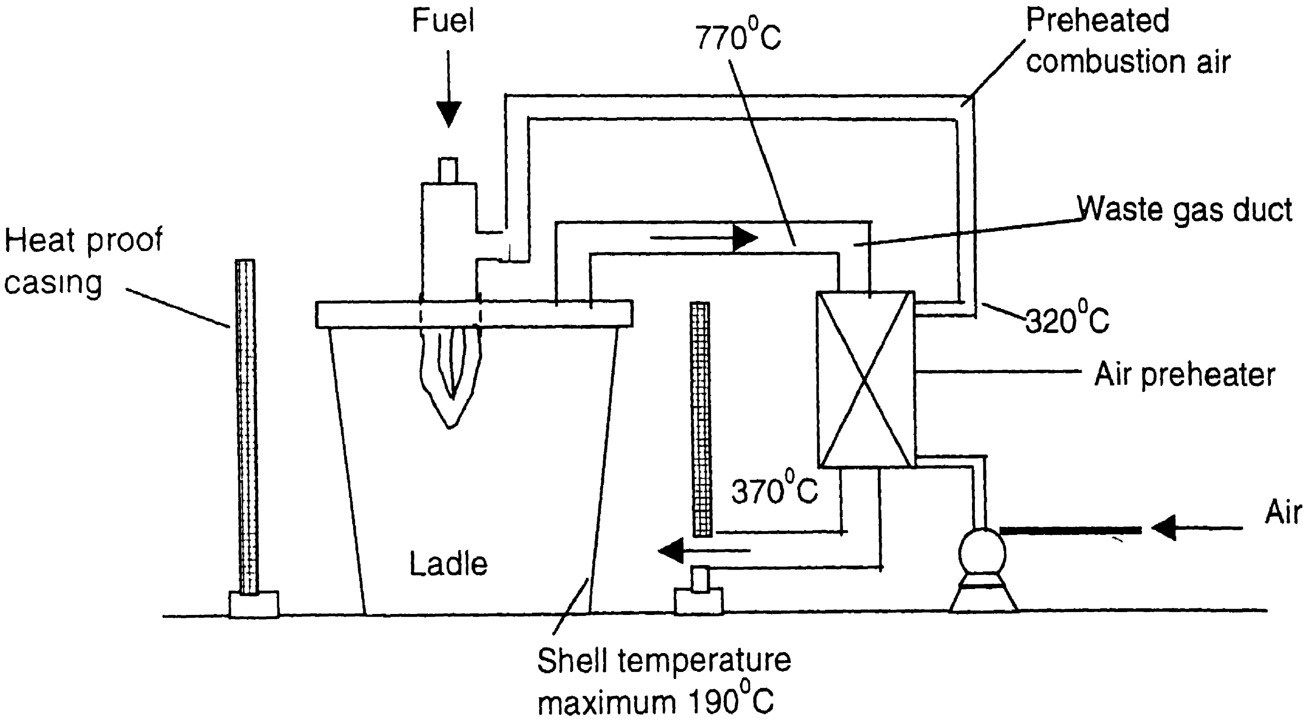
Product Profile:

The energy efficient ladle preheating system incorporates a recuperator in the exhaust gas duct to preheat the combustion air. Furthermore the exhaust gas is used to heat the outer surface of the ladle. The advantages of this system are:

- Combustion air preheat temperatures can reach as high as 320 °C
- The outer surface can be preheated up to 190 °C
- Energy savings in the order of 8-20%
- Uniform distribution of temperature across the refractory
- Reduction in heating cycle

This system of ladle preheating has come into vogue in Germany as a result of search for energy savings. In India, there is no such type of system even though design and development of unit is not complicated. A schematic representation is shown in Fig. 1.

Fig.1 : Schematic Representation of Ladle Pre-heating System



Areas of Application

This system can be applied in Mini steel units (having furnace capacity above 10 Mt.) and using ladles for transport/casting/refining applications.

The installation of such units is simple and doesn't invite any technology transfers, and existing units can be easily replaced. In India, so far no manufacturer developed such packaged units.

Energy Saving Potential

Energy saving potential vary according to the industry and capacity of the ladle. In case of steel industry the energy saving potential is about 8-20%. Estimation of energy saving potential is evaluated by considering a ladle capacity of 50 Mt (Source: Energy audit of a local Iron & Steel Industry conducted by TERI).

Solid Fuels (Coal)

The combustion of solid fuels normally occurs over grates. The general combustion systems for solid fuel are:

a) Over-feed-stoker

Here, coal is fed by dropping it on to the fuel bed. A moving grate imparts forward motion to the coal bed.

b) Travelling or chain grate stoker

This is an endless metal chain conveyor, which carries fuel in to the furnace and ash out of the furnace. The thickness of the fuel bed and spread of the grate control the coal feed rate. Coal containing a high proportion of fines (> 30 %) cannot be burnt, as air passages in the grate are blocked. Coal enters at one end and by the time it reaches the other end, combustion is complete, with ash falling into the ash pit.

c) Under-fired or retort-stoker

Here, fresh fuel is forced into the fire from below, by a screw, and moves out to the sides, as it burns. Burnt fuel and ash automatically move outwards as fresh fuel is forced from below. The advantage is that volatile matter distilled from fresh coal passes through the oxidation zone, ensuring complete combustion.

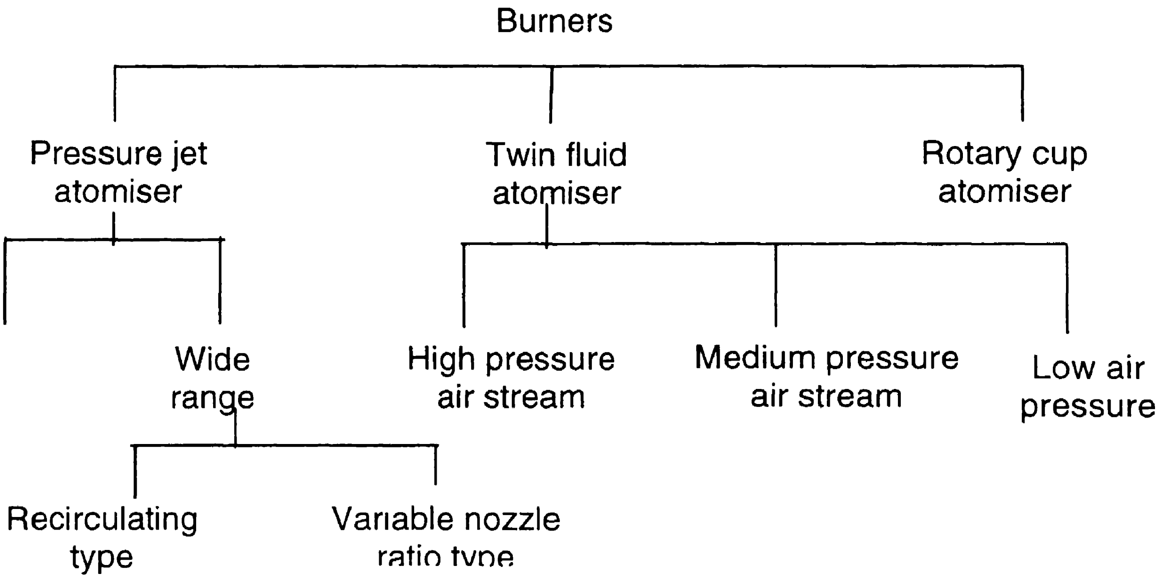
The usual amount of excess air supplied for coal is given below:

Table 1 : Excess Air Supply for Coal

Fuel	Type of Furnace	Excess Air (% by weight)
Coal	Spreader stoker	30 – 60
	Water-cooler vibrating-grate stokers	30 – 60
	Chain-grate and travelling-grate stokers	15 – 50
	Underfeed stoker	20 – 50

Liquid Fuels

The most important component in the combustion of liquid/gaseous fuels is the burner. The main purpose of a burner is to atomise and project the fuel into the combustion chamber. A broad classification of burners, based on the method of atomisation, is given below:



In a twin fluid atomiser, the fuel is injected into the high velocity air stream in one or more discrete jets. In a rotary cup burner, a thin film of oil is formed, by injecting oil into a rapid spinning cup. This film is converted into minute droplets as it leaves the cup, by atomising air fed by the burner.

Pressure jet burners are relatively simpler and inexpensive. However, oil flow rate can be reduced in the simple design, only by reducing oil pressure and hence quality of atomisation. Efficient operation at varying loads usually requires nozzles of various jet sizes.

In medium and high air pressure burners, air for atomising is provided by a compressor at higher pressures. When load changes, the quantity of atomising air is not changed. Only the secondary air entering the system is regulated. Therefore, these burners have better efficiency even at low loads. Compressed air may be replaced by steam as the atomising medium in these burners. Steam aids in cracking of oil in the combustion zone. Steam assisted atomisation is superior for burning heavy fuel oils and LSHS. Medium and high pressure burners should be maintained carefully, since a slight increase in nozzle size can lead to considerable waste of steam or electric power, besides distortion in spray pattern. Atomising air forms a low proportion of total combustion air in these burners. The atomising air velocity is high and combustion intensity increases proportionately. For these reasons, these burners are more popular for high temperature furnaces, where combustion air has to be preheated.

General Requirement for a Burner/Combustion System

For smooth and efficient combustion, fuel should freely ignite as it enters the burning zone, even with load fluctuations within the specified range. The radiation from flame and hot refractory surface and convection from hot gases should be adequate to ignite fresh fuel. The composition of the fuel-primary air mixture should be within limits of inflammability. To obtain the desired rate of heat release, it is necessary to maintain flame stability throughout the combustion process. Burners should not be operated below or above the stipulated range. The flame should not suddenly come in contact with cold air surface. All factors causing flame extinction or flashback must be avoided. Some flame holders enhance flame stability. High temperature combustion proceeds at a finite rate, hence adequate combustion space should be provided for completion. Otherwise loss of combustibles with exhaust gases will also accentuate smoke. Brown smoke is due to the unburnt combustible vapours. Black smoke is due to carbon black produced by chilling of the flame when it impinges on a cold surface. The flame shape should correspond to the geometry of the furnace and vice-versa.

The quantity of air supply is important to achieve proper combustion. Except a few systems, excess air is always required for complete combustion. The method of air supply should be such that there is an intimate contact between oxygen and the combustibles. This is achieved by creating an intense turbulence in the combustion space. The temperature of combustion gases should be maintained in all parts of the combustion chamber, for smooth ignition, stable combustion and smoke-free performance of the system. Theoretically, the most efficient combustion is that which leads to the highest possible temperature.

Selection of Burner

Burner selection, for a particular operation, depends on five design characteristics. Other factors such as increase of primary air pressure and increase or decrease of fuel pressure have very little influence on these characteristics.

Flame Shape

Design of burner, determining the relative velocities of fuel and air, affects flame length and shape the most. Good mixing, produced by a high degree of turbulence and velocity, produces a short bushy flame. On the other hand, delayed mixing and low velocity result in long lazy flames.

Combustion Volume

The space occupied by the fuel and intermediate products of combustion while burning varies considerably with burner design, pressures and velocities of the fluid streams, fuel and application. Gas burners can be designed to have a heat release as high as $110X10^6$ kcal/hr.m^2 of combustion volume. Light oil burners normally operate at the rate of 270000 kcal/hr.m^2 and heavy oil burners at 220000 kcal/hr.m^2.

Stability

This is an important characteristic of a burner, which enables it to maintain ignition under varying conditions of low temperatures, input rates and fuel-air ratios. Improving burner design and providing swirl or jet tubes may enhance stability.

Drive

Drive is the velocity and thrust of the jet stream of hot gases that emanate from a burner. Modern high velocity burners can push hot gases into a loosely piled load with greater velocities than most of the older excess air burners. High velocity burners facilitate re-circulation of gases, improving forced convection. Another advantage of high velocity burners is their ability to reach and wrap around parts of a load that are located away from the burners.

Turndown Ratio

This is the ratio of maximum input rate to minimum. It is the range within which the burner operates satisfactorily. The maximum input rate is limited by a phenomenon called flame blow off, when the mixture velocity exceeds flame velocity. The minimum input rate, on the other hand, is limited by the flashback.

The burner operating parameters are given in the following table :

Table 2 : Burner Operating Parameters

Type of Burner	Pressure	Turn-down Ratio	Capacity Gallons/Hr
Low air pressure	Opil pressure 8 - 12 PSIG Air pressure 24" W.G	1.4:1 (without secondary air) 5:1 (with secondary Air)	1/5 - 60
Medium Air pressure	3 to 15 PSIG (Air)	6 : 1	1/2 - 200
High air pressure	Air pressure 15 PSIG Oil pressure higher	Small - 5:1 Large - 10:1	5 to 500
Steam jet	Dry steam 25-175 PSIG Oil pressure	Small - 5:1 Large 10 : 1	5 to 400
Pressure jet	Oil pressure 50 - 200 PSIG	Simplex 2 : 1 Wide range 6.1 to 10.1	Up to 3000
Rotary cup	1/4 to 30 PSIG	4 : 1	3/4 to 250

In India, bulk of forging production is for the automobile sector. Keeping in tune with the trends abroad use of micro alloys and boron steel over conventional steels is bing considered. Micro-alloys contain vanadium (V) and Niobium(Nb) in small quantities to the extent of 0.05 to 0.2% singly or in combination with the base metal. The advantage of micro alloys lies in their ability to attain a specified strength without quenching and tempering operations. This reduces the heat treatment cost, saves energy and time and also avoids the distortion of the forging, thereby minimizing rejection.

Forging Equipment

Our country lacks capacity to produce sophisticated forging equipment. There are a few companies like, godrej, HMT and NSE who produce good forging equipment of small capacities. Besides these units, forging equipments are also made by small units in Punjab. However, many of the domestic equipment are not conforming to the quality level desired and hence, imports are restored to from Germany, France, UK, USA and Japan.

Salient features of the contemporary international forging technology is as follows

Large screw presses being used with multiple die stations to forge crankshafts and front axles (automobiles).

Computer controlled billets separation and hot shearing lines that produce billet-blanks at higher rates and with very tight weight tolerances.

Press & tooling design modifications to allow quick change over for small and medium lot production.

Modern forging lines using hydraulic hammers with ejectors and specific purpose manipulators Successfully installed for large production lot of forgings

Increase in labour costs and lack of skilled labour in forging industries advanced countries resulting in continuous emphasis on automation. (technical know-how / technologies could be acquired and appropriate adopted by the Indian Industry) area.

Depending on the size of production lots, four main types of automated lines are employed as follows:

Automated or semi-automated press lines for production diesel engine crankshafts, front axles connecting rods and other automobile components.

Automated forging systems with quick die changeover for medium lots of different forgings.

Computer controlled radial forging machines, ring rolling mills, and automated cross rolling machines for performing and finish forging operations.

Automation of work piece transport within forging machines (equipping standard forging equipment with mechanical or pneumatic transfer devices.)

Die Design and Manufacturing

The basic procedures used for die design have not changed significantly in the recent years. The only noteworthy development has been the increased application of analytical and computer aided design (CAD) techniques for the design of pre-forms and finishing dies for forging precision parts. On the manufacturing side, various ways to manufacture dies are copy milling, electrode discharge machining (EDM), hot hobbing, cold hobbing and numerical control machines (NC). Each of these methods has its own field of application. A combination of copy milling and EDM has, however, gained wide acceptability abroad over other techniques.

Heating Systems

Heating for forging is done in fossil -fuel-fired or electrically heated batch, rotary hearth, or pusher type furnaces. In all cases, the chief concern is saving on energy costs. Most of the modern developments in heating systems are in the areas of rapid heating of bar stock, recuperation of heat from the outgoing flue gases and prevention of loss of material due to scale formation.

Abroad, induction and gas heating are increasingly used with the development of efficient furnaces. The advantages of induction heating are quick start up, clean heating with no scale formation, improved environment and compact installation, which saves space.

For high value production of small components, the induction route has several advantages.

- It is easily amenable to automated production
- Very rapid heating enhances productivity
- Heat can be localised to a specific area of the component
- Very low oxidation losses occur with the rapid heat-up rates and short soaking time.
- Attractive levels of thermal efficiency are achieved at point of use, compared with gas-fired units.

Recuperator Heat Exchangers

Recuperator heat exchangers are widely used in forging industry abroad for energy conservation. So far, these exchangers were made from metals which had two shortcomings. Firstly, they had short life and secondly, they were difficult to repair or replace. In recent years, ceramic material has replaced metal in heat exchangers and it offers many advantages like increased life, greater fuel savings, ease of maintenance etc.